Journal of Nannoplankton Research
INA18 abstracts, Avignon, France

INA18 | abstracts | august–september 2022

Institut Pythéas
Observatoire des Sciences de l'Univers
Aix*Marseille Université
cnrs
cerege
CENTRE EUROPÉEN DE RECHERCHE ET D'ENSEIGNEMENT DES GÉOSCIENCES DE L'ENVIRONNEMENT
Aix*Marseille université

International Nannoplankton Association

ISSN 1210-8049 Printed by The Sheridan Press, Hannover PA, USA



Convenors

LUC BEAUFORT CLARA BOLTON BAPTISTE SUCHÉRAS-MARX

Aix-Marseille University — France

Organising Committee

LUC BEAUFORT CLARA BOLTON BAPTISTE SUCHÉRAS-MARX

FRANÇOISE CHALIÉ THIBAULT DE GARIDEL-THORON YVES GALLY JEAN-CHARLES MAZUR

Aix-Marseille University — France

Scientific Committee

BLANCA AUSIN
University de Salamanca — Spain

MICHAËL HERMOSO
Université du Littoral — France

ALICIA KAHN
Chevron —USA

DENISE KULHANEK
Universität zu Kiel — Germany

CHUANLIAN LIU
Tongji University — China

ALEX POULTON
Heriot-Watt University — UK

MARIA TRIANTAPHYLLOU
Panepistímio Athinón — Greece

GIULIANA VILLA
Universitá di Pavia — Italy

Conference Support

CAMILLE GODBILLOT
Aix-Marseille University — France

BLANDINE GODET
University of Lorraine — France

MAJD HABIB
Aix-Marseille University — France

Fieldtrip Contributors

PAULINE COSTER
Luberon Regional Natural Park/UNESCO Global Geopark — France

PHILIPPE LÉONIDE
Aix-Marseille University — France

ALEXIS LICHT
Aix-Marseille University — France

THIERRY TORTOSA
Sainte-Victoire National Natural Reserve — France

INA18 SPONSORS

DIAMOND LEVEL

Institut Pythéas
Observatoire des Sciences de l'Univers
Aix*Marseille Université

Aix*Marseille
université

ASSOCIATION • THE PALAEONTOLOGICAL

cerege
CENTRE EUROPÉEN
DE RECHERCHE ET D'ENSEIGNEMENT
DES GÉOSCIENCES DE L'ENVIRONNEMENT

FRB
FONDATION
POUR LA RECHERCHE
SUR LA BIODIVERSITÉ

PLATINUM LEVEL

StrataData
Biostratigraphic computing

The Micropalaeontological Society

Ellington Geological Services

SILVER LEVEL

FUNDACJA im. GRZYBOWSKI FOUNDATION
Józefa Grzybowskiego
est. - r.zał. 1992

BugWare, Inc.
Oilfield Paleo • Wellsite Specialists

INA International Nannoplankton Association Foundation

Welcome to INA18!

28 August–3 September, 2022

Le Palais des Papes, Avignon

Bienvenue à Avignon!

INA18 is happening after a one-year delay because of the COVID-19 pandemic. This year, travelling is again permitted in many countries, and so meeting here in France is now possible. This meeting will be the perfect occasion for the nanno community to again enjoy in-person exchanges of our latest research and nannoplanktonic adventures. This meeting is taking place in a rare and beautiful Gothic palace dating from the 14th century, from where the popes of that time ruled over a Catholic Europe. This historical place will provide the atmosphere for an enjoyable experience, while sharing our studies on eight main topics related to nannofossils and coccolithophores, including their crystallography, geochemistry, evolution, ecology, biostratigraphy, palaeoceanography, morphometry and taxonomy.

More than 100 participants are going to be gathered in the conference centre in the palace (with 110 registrations), coming from 25 countries, including Argentina (1), Austria (2), Brazil (1), Bulgaria (1), China (9), Colombia (1), Croatia (3), Denmark (1), France (19), Germany (7), Greece (1), India (1), Israel (1), Italy (15), Japan (2), Jordan (1), Philippines (1), Portugal (2), Romania (2), Spain (7), Sweden (4), Switzerland (1), Czech Republic (4), UK (10) and USA (13). INA18 will be showcasing our community's research in 55 oral presentations and 48 posters.

We are sincerely happy that you all made it here!

Luc Beaufort, Clara Bolton and Baptiste Suchéras-Marx
INA18 Convenors
Avignon 2022

INA18 Programme

Monday 29th August

9:00 – 9:20 – **Opening ceremony, welcome and announcements**
Convenors: Luc Beaufort, Clara Bolton & Baptiste Suchéras-Marx

Session 1 – Crystallography and geochemistry
Chairs: Marie-Pierre Aubry & Baptiste Suchéras-Marx
9:20 – 9:40
Young & Bown – The V/R model of heterococcolith biomineralisation 30 years on: Unanswered questions and continuing relevance
9:40 – 10:00
Utsunomiya & Kogure – Morphological and crystallographic variation in coccoliths of the *Umbilicosphaera* (Calcidiscaceae) lineage
10:00 – 10:20
Chowdhury et al. – The mesostructural evolution of *Nannoconus* via ptychographic X-ray computed tomography

Coffee break

Session 1 (cont'd) – Crystallography and geochemistry
10:50 – 11:10
Godet et al. – Experimental diagenesis and quantitative assessment of *Discoaster* overgrowth
11:10 – 11:30
Mutterlose et al. – Provenance analysis of historic mortars and mortar-based materials: A micropalaeontological approach
11:30 – 11:50
Falkenberg & Mutterlose – Burning experiments on calcareous nannofossils: Contribution to a better understanding of historic mortar production
11:50 – 12:10
Giuliana Villa & the INA Committee – Special event

Lunch break

Session 1 (cont'd) – Crystallography and geochemistry
14:00 – 14:20
Bordiga et al. – Silicon in fossil and cultivated coccoliths of *Helicosphaera carteri*: New insights from X-ray fluorescence and infrared spectroscopy analyses
14:20 – 14:40
Chin et al. – Isolating and analysing the coccolith-sized fraction as a metric for diagenesis
14:40 – 15:00
Godbillot et al. – Isotopic response of Pleistocene coccoliths to an ambient pCO_2 change: A calibration experiment
15:00 – 15:20
Le Guevel et al. – Oceanic temperature and pCO_2 reconstruction during the Pliocene in the Caribbean Sea (ODP Site 999) using coccolith geochemistry

15:20 – 17:20 – **Poster session**

17:20 – 18:20
Keynote by **Rosalind E. M. Rickaby** – Perturbing coccolithophores: The past and future of Earth's stabilisers

Tuesday 30th August

Session 2 – Evolution and ecology
Chairs: Camille Godbillot & Ian Probert
9:00 – 9:20
Filatov et al. – How do new phytoplankton species form in the open ocean?
9:20 – 9:40
Beaufort & Dauvier – Evolution of *Gephyrocapsa oceanica*: Equatorial seasonality at play
9:40 – 10:00
Aubry – The heteromorphic haploid–diploid life-cycle of coccolithophores: Insights into genetic fingerprinting, adaptive morphology, phylogeny, and the origin and maintenance of a complex cycle
10:00 – 10:20
Henderiks & Voje – Rates of phenotypic evolution in coccolithophores

Coffee break

Session 2 (cont'd) – Evolution and ecology
10:50 – 11:10
Langer et al. – Distinct physiological responses of *Coccolithus braarudii* life-cycle phases to light intensity and nutrient availability
11:10 – 11:30
Suchéras-Marx et al. – Influence of coccolithogenesis on coccolith size and distribution
11:30 – 11:50
Hagino et al. – Marine phytoplankton biogeography before the recent global ocean warming
11:50 – 12:10
Sheward et al. – Poorly recognised diversity in PIC to POC ratios underpins the role of coccolithophores in the marine carbon cycle

Lunch

Session 3 – Biostratigraphy
Chairs: Emanuela Mattioli & Giuliana Villa
14:00 – 14:20
Demangel et al. – Early evolution of calcareous nannofossils in the Late Triassic in the Neo- and Palaeo-Tethys Oceans
14:20 – 14:40
Rifl & Holcová – Calcareous nannoplankton from the uppermost Triassic in the Southern Alps, Slovenia
14:40 – 15:00
Sheldon et al. – Improving characterisation of the tight Lower Cretaceous marly chalk reservoir, Central North Sea: A nannofossil biostratigraphic, sequence stratigraphic and sedimentological approach
15:00 – 15:20
Kulhanek et al. – Cretaceous–Paleogene calcareous nannofossils from International Ocean Discovery Program Expedition 392 to the Agulhas Plateau, SW Indian Ocean
15:20 – 15:40
De Kaenel et al. – The Paleocene/Eocene boundary and emendation of the NP9/NP10 zonal boundary of Martini (1971)

Coffee break

Session 3 (cont'd) – Biostratigraphy

16:20 – 16:40

Chira & Bindiu-Haitonic – Eocene calcareous nannofossils from the Humor Basin (eastern Carpathians, Romania): Biostratigraphy and palaeoenvironmental reconstruction

16:40 – 17:00

Wang Xuejiao et al. – Regression of the Tethys Sea in Central Asia in the Middle to Late Eocene: Evidence from calcareous nannofossils in the western Tarim Basin, NW China

17:00 – 17:20

Holcová et al. – Strontium isotope stratigraphy vs. calcareous nannoplankton datums in an epicontinental sea: A case study from the Miocene Paratethys

17:20 – 17:40

Vallejo Hincapié et al. – The Neogene Central American seaway

17:40 – 18:00

Lozar et al. – The Lorca Basin revisited: How integrated stratigraphy can help resolve long-standing controversies

18:30 –

External event at the Museum of Natural History (Requien Museum): Opening of the nannofossil art exhibition by **Isabelle Rochemars**

Wednesday 31st August

Session 4 – Palaeoceanography

Chairs: Clara Bolton & José-Abel Flores

9:00 – 9:20

Mattioli et al. – Weakening of the biological pump induced by a nannoplankton crisis during the Early Toarcian Oceanic Anoxic Event

9:20 – 9:40

Bettoni et al. – How did calcareous nannoplankton respond to palaeoenvironmental-factor changes at low and high latitudes across the Late Aptian–Early Albian interval?

9:40 – 10:00

Pige et al. – New estimation of Late Paleocene calcareous nannoplankton fluxes at ODP Site 1209 (North Pacific)

10:00 – 10:20

Alqudah et al. – Calcareous nannofossil assemblages and geochemical analysis of Eocene oil shales from Wadi Ashajara, northern Jordan, and their implications for the depositional environment

Coffee break

Session 4 (cont'd) – Palaeoceanography

10:50 – 11:10

Lukić et al. – Mid-Eocene thermals record in the Istrian Paleogene basin (Outer Dinarides, Croatia), Neotethys

11:10 – 11:30

Ma Ruigang et al. – Nutrient forcing on the Late Middle Eocene to Early Oligocene (~40–31 Ma) evolution of the coccolithophore *Reticulofenestra* (Order Isochrysidales)

11:30 – 11:50

Wang Yasu et al. – Evolution of Miocene calcareous nannofossil assemblages as a response to palaeoceanographic changes in the northern South China Sea

11:50 – 12:10

Mancini et al. – Oligo-monospecific assemblage of calcareous nannoplankton in response to the Messinian palaeoceanographic setting: Insights from the Monte dei Corvi section (central Italy)

Lunch break

14:00 – 16:00 – **Poster session**

16:00 – 18:00

Giuliana Villa, Emanuela Mattioli & the INA Committee – INA business meeting

16:00 – 16:20

Young et al. – Nannotax: Bibliography project and other updates

20:00 –

Gala dinner, Palais des Papes

Thursday 1st September

Session 5 – Quaternary and modern ecology

Chairs: Alba González-Lanchas & Alyssa Peleo-Alampay

9:00 – 9:20

Sun et al. – Blooming coccolithophores identified in the western Pacific during the mid-Brunhes dissolution interval

9:20 – 9:40
Sarao & Kulhanek – Environmental factors influencing calcareous nannofossil distribution over the past 96,000 years in the Panama Basin, eastern equatorial Pacific
9:40 – 10:00
Johnson et al. – Extant coccolithophore distribution in the Mediterranean Sea: A review

10:00 – 10:20
Millán et al. – The coccolithophore community of the Sargasso Sea

Coffee break

Session 5 (cont'd) – Quaternary and modern ecology
10:50 – 11:10
Winter et al. – A high-resolution depth profile of coccolithophores in oligotrophic waters of the North Atlantic Gyre
11:10 – 11:30
Cachão – Calcareous nannoplankton as a useful tool in coastal dynamics and (palaeo)environments
11:30 – 11:50
Grelaud et al. – Coccolithophore ballasting effect on marine microplastics export and accumulation
11:50 – 12:10
Jin et al. – Coccolithophore abundance, degree of calcification and their contribution to particulate inorganic carbon in the South China Sea

Lunch

Session 6 – Morphometry and taxonomy
Chairs: Eric de Kaenel & Rosie Sheward
14:00 – 14:20
Su et al. – Late Quaternary coccolith weight variations in the South China Sea and their environmental implications
14:20 – 14:40
Patil et al. – *Emiliania huxleyi* biometry and calcification response to the Indian sector of the Southern Ocean environmental gradients
14:40 – 15:00
Baumann & Strack – Occurrence and development of *Emiliania huxleyi* morphotypes in the North Atlantic Ocean during the last 290,000 years
15:00 – 15:20
González-Lanchas et al. – Calcification of the *Gephyrocapsa* complex during the Mid-Brunhes Event

Coffee break

Session 6 (cont'd) – Morphometry and taxonomy
16:00 – 16:20
Erba et al. – Morphometric changes in the genus *Watznaueria* in the Toarcian–Aalenian: Implications for taxonomy, biostratigraphy and evolution
16:20 – 16:40
Archontikis et al. – Morpho-taxonomic reassessment of the extant coccolithophores *Ericiolus* and *Mercedesia*
16:40 – 17:00
Varol & Bowman – New Middle Miocene genus *Olladiscoaster*
17:00 – 17:20
Razmjooei & Thibault – Morphometric changes in two Late Cretaceous calcareous nannofossil lineages support diversification fueled by long-term cooling
17:20 – 17:40
Howe – Ultrastructure and taxonomy of the Family Fasciculithaceae

Poster session

Posters

Addante et al. – Coccolithophore distribution in water samples from the Ebro Delta coastal area (Spain)

Alqudah et al. – Calcareous nannofossils from the Samu area (Campanian), northern Jordan

An et al. – Primary production and assemblage composition variations in the coccolithophores of the Gulf of Papua during the past 150 ka

Anton & Melinte-Dobrinescu – Oligocene *Braarudosphaera bigelowii* blooms in Transylvania and the Eastern Carpathians related to palaeoenvironmental changes

Arapov et al. – High-diversity coccolithophore communities in the open central Adriatic Sea

Argenio et al. – IODP Sites U1385 and U1313: Coccolithophore calcification patterns from the Last Glacial Maximum to the Holocene

Asanbe & Henderiks – The biogeographical extent and global synchronicity of the Late Miocene *Reticulofenestra pseudoumbilicus* paracme

Bazzicalupo et al. – Coccolith assemblages inside coralligenous build-ups: Some preliminary results from Marzamemi (Sicily, Italy)

Bazzicalupo et al. – Coccolith assemblages and biomarker response to climate variability in the last 20,000 years in the southern Adriatic Sea

Champigny & Rickaby – Effect of nutrient limitation on the calcification of *Gephyrocapsa oceanica* and *Chrysotila roscoffensis*

Chaumeil-Rodriguez et al. – Early to Middle Jurassic calcareous nannofossil biostratigraphy: A preliminary scheme for southwestern Gondwana

Ćorić & Kallanxhi – Calcareous nannofossils from the Middle/Upper Miocene succession of Pécs-Danitzpuszta (Lake Pannon), southern Hungary

Dauvier et al. – The effects of pelagic carbonate production on the Pleistocene carbon cycle

Fioroni et al. – Nannofossil response to the Late Oligocene warming event at ODP Site 929 (Ceara Rise, western equatorial Atlantic Ocean)

Godbillot et al. – Response of marine nannoplankton to environmental forcings: Insights from automated imaging methods on community shifts in the Gulf of Lions over the last decade

González Martín et al. – Reconstruction of surface-ocean dynamics during Termination V (MIS 12–MIS 11) on the Iberian margin (IODP Site U1386)

González-Lanchas & Rickaby – Coccolith carbon vital effects in understanding the photosynthetic underpinnings of coccolithophore calcification

Granchovski & Stoykova – Campanian–Maastrichtian boundary interval at Beloptichene (Kula tectonic unit, NW Bulgaria): New nannofossil data

Granero Ordoñez & Wagreich – *Aspidolithus parcus*/*Broinsonia parca*: Some aspects of nannofossil morphometry around the Santonian–Campanian boundary

Habib et al. – Evolution and adaptation of coccolithophores to recent environmental changes in the Mediterranean Sea

Hanson & Dunkley-Jones – Novel approaches to high-resolution coccolith geochemistry through the Late Pliocene *Discoaster* extinctions

Hayat et al. – Coccolithophore export production in the deep Ionian Sea, eastern Mediterranean (NESTOR site sediment trap, 4300 m depth)

Holcová & Scheiner – An experimental study on post-mortem dissolution and overgrowth processes affecting coccolith assemblages: A rapid and complex process

Jiang et al. – Upper Cretaceous calcareous nannofossils from Gamba, southern Tibet, and their palaeoceanographic implications

Karatsolis et al. – Middle Miocene to Pleistocene nannofossil biostratigraphy of the North Atlantic: Preliminary results from IODP Expedition 395C, Reykjanes Ridge

Liu et al. – Evolution of Miocene calcareous nannofossil assemblages and palaeoceanographic research in the South China Sea

Marconato et al. – Calcareous nannofossils across the Campanian–Maastrichtian in the high-productivity system of Aderet, Shefela Basin, Israel

Martín García et al. – Messinian–Pliocene chronostratigraphy and palaeoceanography of IODP Site 1387: The calcareous nannofossil washing–winnowing effect

Ma Xiaoxu et al. – Coccolithophore physiology and the molecular mechanism response to the seawater Mg/Ca ratio

Minoletti et al. – Separation of coccoliths from sediments: An automated protocol for palaeoclimatic investigations

Mossell et al. – Surface-water variations during the Middle and Late Pleistocene in the Mozambique Channel based on calcareous nannofossil assemblages

Pedrão et al. – Coccolithophore palaeoproductivity in the SW Atlantic during the last seven terminations

Pérez Panera – Late Triassic calcareous nannofossils from Argentina and Peru unravel an early dispersal pathway through Panthalassa

Persico et al. – Paleogene calcareous nannofossils from IODP Site U1553: Biostratigraphic, palaeoecological and palaeoceanographic implications

Razmjooei et al. – Mid-Pleistocene to Holocene calcareous nannofossil taxonomy and biochronology of the central Arctic Ocean

Rigual-Hernández et al. – Role of coccolithophore floristics on alkenone-derived temperatures in the subantarctic Southern Ocean

Sarkozi & Rickaby – The effect of temperature on the photosynthetic underpinnings of coccolithophore calcification

Schneider et al. – Late Holocene ecological trends in the Levant Basin from fossil phytoplankton assemblages

Shah et al. – Calcareous nannofossil assemblages in sediment cores of the northern Red Sea: First results and palaeoecological reconstructions

Simonato et al. – Correlation of the calcareous nannofossil biostratigraphy between the Cenomanian–Turonian Poigny core and Quero section

Skejić et al. – Coccolithophore assemblages from the central Adriatic Sea

Stoykova et al. – Did the 33.4-Ma eastern Rhodope supereruptions contribute to Early Oligocene cooling? Calcareous nannofossil data from the St. Sozon section, Limnos Island, Greece

Stoykova et al. – PETM Riben section revisited (northern Bulgaria, SE Europe): New nannofossil and foraminiferal isotope data

Svobodová et al. – Jurassic–Cretaceous boundary interval in the Ropice section from the perspective of biostratigraphy, stable isotopes and palaeomagnetism

Trotta et al. – Coccolithophore responses to palaeoenvironmental variability in the Gulf of Cadiz (IODP Site U1387) through MIS 48–MIS 45

Vollmar et al. – Surface-sediment coccolith assemblages and *Emiliania huxleyi* morphotype calcification across the Drake Passage, Southern Ocean

Wang Xuejiao et al. – Interregional correlations and sea-level changes in the Middle Paleocene–Early Eocene of the eastern Tethys Sea (Central Asia): Calcareous nannofossil evidence from the western Tarim Basin, NW China

Zhou & Liu – Evolution of upper seawater stratification in the South China Sea central basin during the Late Miocene

Coccolithophore distribution in a north-western Mediterranean delta system

Marina Addante
Department of Earth and Environmental Sciences, University of Bari Aldo Moro, Bari, Italy & Institut de Ciència i Tecnologia Ambientals, Universitat Autònoma de Barcelona, Bellaterra, Spain; marina.addante@uniba.it

Michaël Grelaud
Institut de Ciència i Tecnologia Ambientals, Universitat Autònoma de Barcelona, Bellaterra, Spain

Patrizia Maiorano
Department of Earth and Environmental Sciences, University of Bari Aldo Moro, Bari, Italy

Marta Alvarez
Instituto Español de Oceanografía, Paseo Alcalde Fco Vazquez Nº10, A Coruña, Spain

Sergio Bonomo
Institute of Environmental Geology and Geoengineering, National Research Council (IGAG-CNR), Monterotondo (RM), Italy

Patrizia Ziveri
Institut de Ciència i Tecnologia Ambientals, Universitat Autònoma de Barcelona, Bellaterra, Spain

Coccolithophores are considered to be dominant in pelagic and oligotrophic systems. For this reason, there is a lack of studies in coastal areas. We present the living coccolithophore distribution and diversity in the Catalan coastal area from Barcelona to the Ebro Delta (Spain), as revealed by the analysis of 77 water samples from 11 hydrographic stations sampled during the MERS research cruise (24–28 November, 2019). The sampled transects span the coastal and offshore systems from 5–200 m water depth. The coccolithophore distribution was integrated with the seawater environmental parameters (nutrients, carbonate chemistry, light penetration, salinity, etc.) collected during the cruise. The most abundant coccolithophore species at all the stations was *Emiliania huxleyi*, likely related to the sampling season (end of summer stratification and increase in nutrient availability), followed by subordinate species, such as *Gephyrocapsa* spp., *Syracosphaera* spp., *Algirosphaera robusta*, *Helicosphaera carteri*, *Rhabdosphaera* spp., *Coronosphaera mediterranea*, *Calciosolenia* spp. and *Florisphaera profunda*. At the 11 sampled stations, the highest cell concentrations generally occurred within the top 50 m of the water column. The maximum coccolithophore standing stocks were recorded between 5 and 50 m. The highest standing stocks occurred in the nearshore stations (5.1×10^4 coccospheres/L), associated with vertical mixing and the nutrient supply from river input. No clear vertical species zonation was observed in these shallow-water stations, nor a significant variation in the environmental parameters with depth, suggesting a rather homogeneous and mixed water-column. Moving from more coastal to offshore stations, a slight decrease in CD occurred. In the offshore stations, the standing stock peaks were deeper and had lower values, and despite the dominance of *E. huxleyi*, a vertical zonation in the community was observed. An upper-photic-zone (UPZ) group (*Rhabdosphaera* spp., *Syracosphaera pulchra*, *C. mediterranea*, *Syracosphaera anthos*, *Umbellosphaera tenuis* and *Discosphaera tubifera*), although rare, occurred in the top 50 m, while the deep-dwellers—*F. profunda* and *Gladiolithus flabellatus*—occupied the lower photic zone (LPZ) from 75 m. The present study addresses the lack of knowledge of coccolithophore ecology in coastal environments.

Calcareous nannofossil assemblages and geochemical analysis of Eocene oil shales from Wadi Ashajara, northern Jordan, and their implications for the depositional environment

Mohammad Alqudah
Department of Earth and Environmental Sciences, Faculty of Science, Yarmouk University, Shafeeq Irsheidat Street, 21163 Irbid, Jordan; mohammad.alqudah@yu.edu.jo

Ali Momani
Department of Physics, Faculty of Science, Yarmouk University, Shafeeq Irsheidat Street, 21163 Irbid, Jordan

Mahmoud H. Altamimi, Jamal Nazzal, Mohammad S. Atawneh
Department of Earth and Environmental Sciences, Faculty of Science, Yarmouk University, Shafeeq Irsheidat Street, 21163 Irbid, Jordan

Eocene oil-shale deposits are particularly interesting among the organic-rich deposits in Jordan due to their deposition in the latest stage of the closure of the Neo-Tethys. Twenty-one oil-shale samples from the Wadi Ashajara section were analysed for calcareous nannofossils and their biostratigraphy, palaeoecology, isotopic components and inorganic geochemistry. These proxies offered some important insights into the depositional environment of the organic-rich sedimentation during the Eocene. Based on the first occurrences of the marker-species *Discoaster sublodoensis*, *Nannotetrina quadrata* and *Discoaster bifax*, the Ashajara section was assigned to the Middle Eocene. Palaeoecologically, many genera thrived during the Middle Eocene Climatic Optimum event. Significant increases in the abundances of *Reticulofenestra* spp. and *Coccolithus* spp. during NP16 revealed a period of eutrophy dominating in the ocean in the Middle Eocene. The clear shift in ecological strategy correlated with periods of increased nutrient supply (Fe, P, Al and Si), suggesting that climate played a major role in increasing the abundance of the primary producers, therefore enhancing the organic-rich environment in northern Jordan. Ecological shifts in the calcareous nannofossils were also associated with shifts in oxygen, carbon, uranium and potassium isotopes. The presence of redox-sensitive elements (Fe, Ni and Cr) suggests that the oil shale in the study area was generally deposited in an anoxic environment. However, in some parts of the oil shale, elements with strong euxinic affinities (Mo, Zn and V) exhibit the strongest enrichment, which in turn indicates deposition of the oil shales in a euxinic to sub-euxinic environment.

Calcareous nannofossils from the Samu Area (Campanian), northern Jordan

Mohammad Alqudah, Haneen Ali Al-Sawaie, Waleed A. Al-saqqa
Department of Earth and Environmental Sciences, Faculty of Science, Yarmouk University, Shafeeq Irsheidat Street, 21163 Irbid, Jordan; mohammad.alqudah@yu.edu.jo

Calcareous nannofossil assemblages were examined from the Campanian chalks of Wadi Samu in northern Jordan for their biostratigraphy and palaeoecology. Samples were taken from a 30-m section composed mainly of chalk resting unconformably on Santonian dolomitic limestones and underlain by chert–limestone sequences. The palaeoecological analysis of the calcareous nannofossils in the studied samples depended on a set of statistical indices, including the total number of nannofossils, their abundance, diversity, fertility and productivity. In addition, some species were selected to determine temperature fluctuations in the surface water that might indicate colder or warmer conditions. The calcareous nannofossil assemblages in the Wadi Samu section had high diversity, with high abundances in particular genera, such as *Watznaueria* spp. and *Arkhangelskiella* spp., which had good to moderate preservation. The logged section was divided into two biozones (UC14 and UC15) based on the marker species. The palaeoenvironmental analysis emphasised the significance of cooling and fertility indicators, based on the preferences of nannofossil taxa in the reconstruction of climate and productivity models for the Tethyan Realm. Three intervals were characterised by cooler climates and the dominance of a eutrophic regime in the Campanian. The dominance of cooler-water species, such as *Arkhangelskiella confusus*, *Eiffellithus turriseiffelii* and *Zeugrhabdotus erectus*, in the three intervals associated with high-nutrient species, such as *A. confusus* and *Z. erectus*, indicated the preference of these species for lower palaeotemperatures and high-nutrient regimes.

Variations in primary productivity and assemblage composition of coccolithophores in the Gulf of Papua over the past 150 ka

Baizheng An
Linyi University, Linyi 276000, China; an.baizheng@gmail.com
Hanjie Sun
Key Laboratory of Marine Geology and Environment, Institute of Oceanology, Chinese Academy of Sciences, Qingdao 266071, China
Luc Beaufort
Aix-Marseille University, CNRS, IRD, INRAE, CEREGE, Aix-en-Provence, France
Tiegang Li
Key Laboratory of Marine Sedimentology and Environmental Geology, First Institute of Oceanography, SOA, Qingdao 266061, China

The calcite plates that compose the exoskeletons of coccolithophores have a strong impact on the calcium carbonate transport flux from the sea surface to deep water. In this study, we used two Late Pleistocene sediment cores from the Gulf of Papua (Western Pacific; MD05-2049, MD05-2950). The changes in coccolith assemblage compositions and palaeo-primary productivity over the past 150,000 years were reconstructed based on over 500 samples extracted from the sediment cores. The samples were prepared using the random settling method, and then 150 fields of view were imaged for each sample using a SPOTFLEX camera. All the calcareous nannofossil were then identified and counted automatically using the SYRACO system. The calcareous nannofossil assemblages were dominated by *Florisphaera profunda* and members of the Noelaerhabdaceae (*Gephyrocapsa* and *Emiliania*).

We estimated the primary productivity conditions of the two cores based on the percentage of *F. profunda*. Preliminary results show a correlation between primary productivity and precession in both cores. During MIS 5b–5a, the lowest primary productivity (about 150 g C m^{-2} a^{-1}) occurred at 82 ka BP, with strong seasonality indicated by high precession values during this period. During MIS 5b–5a, the percentage of *Gephyrocapsa ericsonii* also decreased, from 60% to 20%. *Gephyrocapsa oceanica* also varied following the primary productivity changes, with a higher percentage when primary productivity was high, and a lower percentage when the primary productivity was low. However, *Calcidiscus leptoporus* (contributing less than 1% to the coccolith assemblages) showed the opposite trend, with a higher percentage when the primary productivity was lower. It is possible that different coccolithophores have different strategies for surviving in variable environments. *Gephyrocapsa oceanica* easily dominates under high-productivity conditions, whereas *C. leptoporus* may have a better chance of survival under low-productivity conditions when other phytoplankton are constrained by environmental factors.

Oligocene *Braarudosphaera bigelowii* acmes in Transylvania and the Eastern Carpathians related to palaeoenvironmental changes

Eliza Anton, Mihaela Melinte-Dobrinescu

National Institute of Marine Geology and Geo-Ecology (GeoEcoMar), 23–25 Dimitrie Onciul St., 024053 Bucharest, Romania; antoneliza@geoecomar.ro

Blooms of *Braarudosphaera bigelowii* are known to appear in several intervals, from Cretaceous times up to the Holocene. It seems that this species is an opportunistic one that flourishes when surface-water salinity is considerably changed. Here, we focus on *B. bigelowii* occurrences in Romania in various Oligocene depositional settings. From the Eocene–Oligocene boundary, when the Tethyan domain divided into the Mediterranean and the Paratethys, significant palaeogeographical changes took place in Central and Eastern Europe, implying a restricted circulation for the latter realm and the occurrence of endemic faunas and floras. The salinity shifted across the whole Paratethyan region, including in Transylvania and the Eastern Carpathians, where anoxic deposition occurred.

Analysis of the Lower Oligocene calcareous nannofossils from the aforementioned regions has highlighted the occurrence of *B. bigelowii* acmes (representing around 60–70% of the total assemblages) in NP22 and NP23 (lower part). This interval contains, besides *B. bigelowii*, a small number of taxa (such as *Reticulofenestra bisecta*, *R. umbilicus*, *R. hillae*, *R. lockeri*, *Cyclicargolithus floridanus* and *Sphenolithus moriformis*), all of them with low abundances.

Bulk sediment samples enriched in braarudosphaerids were characterised by increased values of $\delta^{18}O$. Up-section, in NP23, the $\delta^{18}O$ showed a decrease concomitant with lithological change (i.e. the deposition of laminated coccolithic limestones). We speculate that the *B. bigelowii* acmes represent a single palaeogeographical/palaeoclimatic event, Early Oligocene (Rupelian) in age, linked to regional (i.e. restricted circulation following isolation of the Paratethys domain) and also global causes, related to the overall climatic deterioration during that time.

High-diversity coccolithophore communities in the open central Adriatic Sea

Jasna Arapov, Ana Bakrač, Sanda Skejić, Mia Bužančić, Živana Ninčević Gladan

Institute of Oceanography and Fisheries, Šetalište I. Meštrovića 63, 21000 Split, Croatia. arapov@izor.hr

A vertical profile of a coccolithophore community was analysed using a scanning electron microscope (FESEM Tescan MIRA3) in 2018. Sampling was conducted monthly at standard oceanographic depths (0, 10, 20, 30, 50, 75 and 100 m). A total of 77 samples were analysed, with at least 100 cells being determined in each sample. The results showed high diversity, with at least 133 morphotypes, out of which 84 species were in the heterococcolith and 42 in the holococcolith phase.

The species *Emiliania huxleyi* was the most abundant and the most frequently occurring, while the *Syracosphaera* genus was the most diverse, represented by 30 species. The contribution and diversity of holococcolithophore morphotypes were significantly higher in the upper photic zone to 30 m depth in the period from April to October. An extreme peak in HOL contribution was noticed in May in the deeper layers (at 75 and 100 m). Throughout the investigated period, eight species were found as possible combination coccospheres—*Algirosphaera robusta*, *Helicosphaera pavimentum*, *Syracosphaera arethusae*, *S. bannockii*, *S. molischii*, *S. nodosa*, *S. pulchra* and *Pontosphaera japonica*. Besides the combination coccospheres of *S. molischii* and *S. pulchra* that were the most often recorded, the others were found only as single specimens, and some in collapsed form. In general, combination coccospheres were mainly found at the surface or at 10 m deep, with the greatest occurrence in April. The exceptions were six combination coccospheres of *S. pulchra* COMB *pirus* in October at 50 m, and a single combination coccosphere of *S. arethusae* at 75 m.

Some recently described species were identified, including *Calyptrosphaera lluisae* Keuter, Young, Koplovitz, Zingone & Frada, 2021, *Calicasphaera bipora* Keuter et al., 2021, *Palusphaera crosiae* Archontikis & Young, 2021 and possibly *Syracosphaera mediterranea* HOL *marisrubi* type. In addition, the species *Alisphaera pinigera*, *Gephyrocapsa ericsonii ericsonii* type, *G. ericsonii protohuxleyi* type, *G. oceanica*, *Reticulofenestra sessilis*, *Syracosphaera azureaplaneta*, *Pileolosphaera longistirpes*, *Oolithotus fragilis*, *Hayaster perplexus* and *Zygosphaera marsilii* are newly reported from the Adriatic Sea.

Morpho-taxonomic reassessment of the extant coccolithophores *Ericiolus* and *Mercedesia*

Odysseas A. Archontikis
Department of Earth Sciences, University of Oxford, South Parks Road, Oxford OX1 3AN, UK; odysseas.archontikis@univ.ox.ac.uk
Josué G. Millán, Amos Winter
Department of Earth and Environmental Systems, Indiana State University, Terre Haute, Indiana, USA
Jeremy R. Young
Department of Earth Sciences, University College London, Gower Street, London WC1E 6BT, UK

The genera *Ericiolus* Thomsen and *Mercedesia* Thomsen & Østergaard are distinctive extant coccolithophores that are characterised by monomorphic, monothecate coccospheres formed of small-sized, star-shaped nannoliths. Following a review of SEM images from Mediterranean, Pacific and Atlantic waters, 26 collapsed coccospheres with star-like nannoliths were identified. Observations on the morphologies and biometric assessments of these specimens revealed the existence of two unreported morphotypes that differ morphologically from all currently known *Ericiolus* and *Mercedesia* species. The results suggest that the two morphotypes possess nannoliths with, respectively: 1) three bifurcate rays, equally positioned and angled, and a central spine with a terminal knob; and 2) three coplanar rays with small bifurcations at their tips and delicate crystal laths extending up the rays. Based on this and a re-examination of previously published species, we further discuss the taxonomic implications for the genera *Ericiolus* and *Mercedesia*.

IODP Sites U1385 and U1313: Coccolithophore calcification patterns from the Last Glacial Maximum to the Holocene

Carmen Argenio
Dipartimento di Scienze e Tecnologie, Università degli Studi del Sannio, Benevento, Italy; argenio@unisannio.it

José Abel Flores
Department of Geology, Universidad de Salamanca. Salamanca, Spain

Miguel Ángel Fuertes
Department of Didactics of Mathematics and Experimental Sciences, Universidad de Salamanca, Salamanca, Spain

Barbara Balestra
Environmental Science Department, American University, Washington, DC, USA & Paleobiology Department, National Museum of Natural History, Smithsonian, Washington, DC, USA & Institute of Marine Sciences, University of California–Santa Cruz, Santa Cruz, CA, USA

Filomena Ornella Amore
Dipartimento di Scienze e Tecnologie, Università degli Studi del Sannio, Benevento, Italy

The study of calcareous nannofossil assemblages from Integrated Ocean Drilling Program (IODP) Sites U1385 and U1313 has allowed us to document the climate transitions that occurred in the Atlantic Ocean since the Last Glacial Maximum (LGM). The present study compared coccolith-based palaeoproductivity proxies, calcification and dissolution/preservation signals to provide a palaeoceanographic reconstruction of sea-surface dynamics.

The calcification of all analysed species showed a decrease from 25 ka towards the Holocene, testifying to a negative influence of higher CO_2 values on nannoplankton calcification. This link was more evident at Site U1313, where size-normalised coccolith thicknesses were reduced during intervals of increased CO_2, including the Heinrich Stadial 1 (HS1), the Bølling–Allerød (B–A), the Younger Dryas (YD) and the Holocene. The parameter controlling calcification during Heinrich events differed at the two latitudes—at Site U1385, it was mainly controlled by temperature, while at Site U1313, it was hampered by poor light availability due to iceberg influence. Furthermore, the palaeo-assemblages at Site U1313 were characterised, during HS1 and at the beginning of the LGM, by dissolution related to the effects of the higher CO_2 solubility in the colder ice-age ocean, as well as temperature. At Site U1313, contrary to Site U1385, the constantly increasing CO_2 concentration recorded during the B–A hampered both calcification and the degree of preservation.

The biogeographical extent and global synchronicity of the Late Miocene *Reticulofenestra pseudoumbilicus* paracme

Joseph Asanbe, Jorijntje Henderiks
Department of Earth Sciences, Uppsala University, SE-752 36 Uppsala, Sweden; asanbejoseph@gmail.com

First documented in deep-sea sites in the tropical Indian Ocean and defined as the "small *Reticulofenestra* interval" (Young, 1990) and the "*Reticulofenestra pseudoumbilicus* paracme" (Rio et al. 1990), the temporary disappearance of *R. pseudoumbilicus* (>7 μm) during the Late Miocene lasted ~1.6 Myr (Backman & Raffi, 1997). In this study, datasets from 49 deep-sea drilling (DSDP, ODP and IODP) sites from all major ocean basins were reanalysed to evaluate the global extent and timing of the *R. pseudoumbilicus* paracme. Reported nannofossil bioevents were updated to the latest geological time-scale to create a robust biostratigraphic framework for basin-to-basin as well as latitudinal comparisons. This analysis confirmed a prominent distribution of the paracme in the tropical and subtropical regions, where its timing was largely synchronous. However, a later onset and shorter duration of the paracme at higher latitudes suggest that *R. pseudoumbilicus* 'left' the tropics first and remained in temperate regions for a much longer time. As already suggested by Young (1990), these patterns are most likely the result of a combination of evolutionary controls and ecological influences.

Quantitative nannofossil analyses of ODP Site 806 (Ontong Java Plateau, western equatorial Pacific) have provided support for drastic ecological changes prior to the disappearance of *R. pseudoumbilicus*. Basin-wide increases in bulk biogenic carbonate accumulation rates, denoting the start of the Late Miocene 'biogenic bloom', indicate large-scale changes in pelagic export production in the tropics around the same time. We hypothesise that the *R. pseudoumbilicus* paracme represents an ecology-influenced, regional extinction in the tropics or a migration to higher latitudes, where it remained for another ~1.2–1.4 Myr before going extinct. Although it may have survived for a longer time at higher latitudes, the reappearance of large *Reticulofenestra* morphospecies ~400–600 kyr later probably involved substantial genetic change, in analogy to the repeated extinction and speciation cycles proposed for Pleistocene *Gephyrocapsa* morphospecies (Matsuoka & Okada, 1990; Bendif et al., 2019).

References

Backman, J. & Raffi, I. 1997. Calibration of Miocene nannofossil events to orbitally tuned cyclostratigraphies from Ceara Rise. *In*: N.J. Shackleton et al. (Eds). *Proceedings of the Ocean Drilling Program, Scientific Results*, **154**: 83–99.

Bendif, E.M., Nevado, B., Wong, E.L.Y., Hagino, K., Probert, I., Young, J.R., Rickaby, R.E.M. & Filatov, D.A. 2019. Repeated species radiations in the recent evolution of the key marine phytoplankton lineage *Gephyrocapsa*. *Nature Communications*, **10**: 4234.

Matsuoka, H. & Okada, H. 1990. Time progressive morphometric changes of the genus *Gephyrocapsa* in the Quaternary sequence of the tropical Indian Ocean, Site 709. *In*: R.A. Duncan et al. (Eds). *Proceedings of the Ocean Drilling Program, Scientific Results*, **115**: 225–270.

Rio, D., Fornaciari, E. & Raffi, I. 1990. Late Oligocene through Early Pleistocene calcareous nannofossils from western equatorial Indian Ocean (Leg 115). *In*: R.A. Duncan et al. (Eds.). *Proceedings of the Ocean Drilling Program, Scientific Results*, **115**: 175–235.

Young, J. 1990. Size variation of Neogene *Reticulofenestra* coccoliths from Indian Ocean DSDP cores. *Journal of Micropaleontology*, **9**: 71–86.

The heteromorphic haploid–diploid life-cycle of coccolithophores: Insights into the genetic fingerprint, adaptive morphology, phylogeny, origin and maintenance of a complex cycle

Marie-Pierre Aubry
Department of Earth and Planetary Sciences, Rutgers University, 610 Taylor Road, Piscataway, NJ 08854-8066, USA; aubry@eps.rutgers.edy

The coccolithophores may be the most iconic example of an organism with a haplo-diplobiontic life-cycle, with a dimorphism so extreme that their exoskeletons were commonly assigned to separate species and genera when first described. A wealth of data has been recorded for the diploid phase of the coccolithophores, with comprehensive syntheses of their biology, ecology and phylogeny. By contrast, knowledge of the more fragile haploid phase has lagged to an extent that prevents a holistic approach to the study of coccolithophores in general.

This study was an attempt to remedy this chaotic situation. Based on a comprehensive description of the morphology and structure of all described coccoliths and coccospheres secreted during the haploid phase, and a comparison between those that are paired with a diploid counterpart and those that are not, an inclusive biological framework was established that unites the haploid and diploid phases.

The implications of this effort are examined, including the leading role of morphostructural analysis in guiding the interpretation of molecular phylogeny inferred from environmental databases, the modalities of adaptive morphology in oligotrophic waters, and the origination of a strongly differentiated haplo-diploid life-cycle in the earliest coccolithophores. Importantly, the coccolithophores offer a unique opportunity to analyse the differences in phenotypic expressions of the genome of a species during its haploid and diploid phases.

References

Aubry, M.-P. 2022. Coccolithophores: The calcifying haploid phase in living species. Biology, adaptive morphology, taxonomy. *SEPM Concepts in Sedimentology and Paleontology*, **15**: 402 pp.

Occurrence and development of *Emiliania huxleyi* morphotypes in the North Atlantic Ocean during the last 280,000 years

Karl-Heinz Baumann
University of Bremen, Department of Geosciences, Klagenfurter Strasse 2-4, D-28359 Bremen, Germany; baumann@uni-bremen.de
Anne Strack
University of Bremen, MARUM – Center for Marine Environmental Sciences, Leobener Strasse 8, D-28359 Bremen, Germany

The currently accepted *Emiliania huxleyi* morphotype classification is entirely based on modern samples, and the stratigraphic range of distinct morphotypes is unknown. Therefore, the main objective of this study was to investigate the occurrence of known *E. huxleyi* morphotypes in the fossil record in the North Atlantic Ocean. Counts of morphometric coccolith parameters were conducted using SEM, and measurements of these parameters on SEM images were analysed by discriminant analyses. The visual assignment of distinct coccoliths to known *E. huxleyi* morphotypes was validated by group assignments using a leave-one-out cross-validation procedure.

Four known *E. huxleyi* morphotypes were distinguished—three lightly calcified (Types A, B/C and O) and one heavily calcified (here named Type T), which corresponds to the known Type A overcalcified morphotype. Furthermore, a new *Reticulofenestra*-like morphotype (Type R*) was observed, which is characterised by extensive distal-shield calcification. All investigated records showed a similar, but diachronous, size evolution of *E. huxleyi* coccoliths, with the largest coccolith sizes occurring during MIS 4 and MIS 3. An increasing size trend with higher latitude, involving up to 30% larger coccoliths, was also observed. In addition, low-latitude records showed a dominance of *E. huxleyi* Type O, although this morphotype has previously been considered as a cold-water indicator. The results were validated in the context of information available from the cores.

Coccolith assemblages inside coralligenous build-ups: Preliminary results from Marzamemi (Sicily, Italy)

Pietro Bazzicalupo, Elisa Malinverno
Department of Earth and Environmental Sciences, University of Milano–Bicocca, Milano, Italy; pietro.bazzicalupo@unimib.it

Valentina Alice Bracchi
Department of Earth and Environmental Sciences, University of Milano–Bicocca, Milano, Italy & CoNISMa – National Inter-University Consortium for Marine Sciences, Roma, Italy

Andrea Giulia Varzi
Department of Earth and Environmental Sciences, University of Milano–Bicocca, Milano, Italy

Alessandra Savini
Department of Earth and Environmental Sciences, University of Milano–Bicocca, Milano, Italy & CoNISMa – National Inter-University Consortium for Marine Sciences, Roma, Italy

Luca Fallati
Department of Earth and Environmental Sciences, University of Milano–Bicocca, Milano, Italy

Adriano Guido
Department of Biology, Ecology and Earth Sciences, University of Calabria, Cosenza, Italy

Antonietta Rosso, Rossana Sanfilippo, Riccardo Leonardi
CoNISMa- National Inter-University Consortium for Marine Sciences, Roma, Italy & Department of Biological, Geological and Environmental Sciences, University of Catania, Catania, Italy

Mauro Pietro Negri
Department of Earth and Environmental Sciences, University of Milano–Bicocca, Milano, Italy

Mara Cipriani
Department of Biology, Ecology and Earth Sciences, University of Calabria, Cosenza, Italy

Daniela Basso
Department of Earth and Environmental Sciences, University of Milano–Bicocca, Milano, Italy & CoNISMa – National Inter-University Consortium for Marine Sciences, Roma, Italy

In the Mediterranean Sea, crustose coralline algae form endemic mesophotic reefs known as coralligenous build-ups. These reefs are major hotspots for biodiversity and are characterised by a complex algal skeletal carbonate structure that supports many organisms inside their numerous holes and crevices. In addition, the high porosity of these structures leads them to act as sediment traps, potentially storing climatic and/or hydrological information.

Previous studies have investigated the composition of the sediments trapped inside coralligenous structures, although no studies have focused specifically on coccoliths. Because coccoliths are a well-known proxy for stratigraphic, climatic and hydrological changes, coccoliths trapped in coralligenous build-ups could potentially help us to understand the growth of the bioconstruction.

Samples from two coralligenous build-ups were collected during the project FISR 04543 'CRESCIBLUREEF—Grown in the blue: New technologies for knowledge and conservation of Mediterranean reefs' (https://cresciblureef.unimib.it/) from 36 and 37 m water depth off the coast of Marzamemi village (Sicily, Ionian Sea). Here, we present our preliminary findings on the coccolith assemblages retrieved from inside these build-ups.

Abundant reworked coccolith taxa testify to river runoff/land erosion, reflected in the age of the taxa being in accordance with the stratigraphy on land. In addition, several extant taxa were identified. Given the relatively good preservation and the known stratigraphic distributions, we suggest that nannoplankton sedimentation from the upper water-column occurred during build-up development, highlighting the role of these bioconstructions as coccolith-snow traps. These findings represent a preliminary assessment of the possibility of coupling coccolith analysis with coralligenous build-up studies, helping to assess the hydrological/environmental changes affecting the coralligenous build-ups during their lifespans. In this sense, comparisons between the coccolith assemblages and other biogenic components and the terrigenous sediments inside the coralligenous build-ups could be a powerful tool for unravelling local/regional hydrological and climatic changes.

Coccolith assemblages and the biomarker response to climate variability over the last 20,000 years in the southern Adriatic Sea

Pietro Bazzicalupo
Department of Earth & Environmental Sciences, University of Milano–Bicocca, Milano, Italy & Department of Earth & Geoenvironmental Sciences, Università degli Studi di Bari Aldo Moro, Bari, Italy; pietro.bazzicalupo@unimib.it

Marie-Alexandrine Sicre, Vincent Klein
LOCEAN, Sorbonne Universités (UPMC, Univ. Paris 06)-CNRS-IRD-MNHN, Paris, France

Patrizia Maiorano
Department of Earth & Geoenvironmental Sciences, Università degli Studi di Bari Aldo Moro, Bari, Italy

The southern Adriatic Sea is a well-known area of high climatic sensitivity in the Mediterranean Sea, characterised by a surface-water circulation deeply affected by wind stress and river runoff. These characteristics make it extremely well suited to studying the last deglaciation and the Holocene, a period marked by vigorous long- and short-term climatic fluctuations (e.g. Siani et al., 2013; Jalali et al., 2018). In this work, we generated a high-resolution multi-proxy reconstruction (average of 80 yrs/sample), based on coccolithophore assemblages and marine and terrestrial biomarkers from the deep-sea marine core ND14Q-AR2, retrieved from the South Adriatic Pit at 1013 m below sea level. The core has a robust age-depth model, based on several tephra layers covering the last 20 kyr BP and 10 radiocarbon dates (Totaro et al., 2022).

The coccolithophore assemblages clearly show orbital-scale variations and short-term millennial- to centennial-scale climate variability. These variations, interpreted as reflecting changes in the temperature, salinity and productivity of the surface waters, were used to shed more light on coccolithophore behaviour in the Adriatic Sea, which has thus far been poorly explored. Marine biomarkers (alkenones) were used to reconstruct the sea-surface temperatures (SSTs) and assess the organic-matter deposition on the seafloor. Terrestrial biomarkers (n-alkanes, synthesised by terrestrial higher plants) were measured to evaluate the terrigenous input into the Adriatic Basin, as well as the humidity changes on land. These records clearly evidence the known climatic phases of the last 20,000 years, such as the Heinrich Stadial 1 (HS1), the Bølling–Allerød (B–A), the Younger Dryas (YD) and the Holocene. Several centennial- and millennial-scale events (such as the Holocene Rapid Climate Changes [HRCCs]) superimposed on these main climatic trends were also identified. The continental and marine proxies highlighted both a long-term temperature and humidity increase and short-term wet–dry phases affecting the surface waters and marine productivity through freshwater discharge and terrigenous input. The overall analysis underlined the ability of calcareous nannofossils and biomarkers to capture high-frequency climatic fluctuations in the Adriatic Sea.

References

Jalali, B., Sicre, M.-A., Klein, V., Schmidt, S., Maselli, V., Lirer, F., Bassetti, M.A., Toucanne, S., Jorry, S.J., Insinga, D.D., Petrosino, P. & Châles, F. 2018. Deltaic and coastal sediments as recorders of Mediterranean regional climate and human impact over the past three millennia. *Paleoceanography and Paleoclimatology*, **33**: 579–593.

Siani, G., Magny, M., Paterne, M., Debret, M. & Fontugne, M. 2013. Paleohydrology reconstruction and Holocene climate variability in the south Adriatic Sea. *Climate of the Past*, **9**: 499–515.

Totaro, F., Insinga, D.D., Lirer, F., Margaritelli, G., i Caparrós, A.C., de la Fuente, M. & Petrosino, P. 2022. The Late Pleistocene to Holocene tephra record of ND14Q site (southern Adriatic Sea): Traceability and preservation of Neapolitan explosive products in the marine realm. *Journal of Volcanology and Geothermal Research*, **423**: 107461.

Evolution of *Gephyrocapsa oceanica*: Equatorial seasonality at play

Luc Beaufort, Josué Dauvier
Aix-Marseille University, CNRS, IRD, INRAE, CEREGE, Aix-en-Provence, France; beaufort@cerege.fr

Today, there is virtually no seasonal change at the Equator because Earth orbits the sun in a nearly circular orbit. This orbit has periodically been more eccentric, producing a significant annual asymmetry in the amount of sunlight received at the Equator, which we call equatorial seasonality (ES). The evolution of the Noelaerhabdaceae has recently been shown to have been driven by ES cycles (Beaufort et al., 2022). Another study has shown that the extant species of the Noelaerhabdaceae evolved from a common ancestor that lived 500 ka by progressively diverging in size towards the present large spectrum of species-specific coccolith lengths (Bendif et al., 2019). This presentation will illustrate our quantification of the evolution of coccolith length in one of these species—*Gephyrocapsa oceanica*—over the last 500 kyr. We measured the sizes of more than 100 *G. oceanica* coccoliths in high-resolution samples collected from six cores selected from the Indian and Pacific Oceans and the Mediterranean Sea.

These records of *G. oceanica* coccolith size show similar trends—their size increased progressively from 500 ka to 100 ka, then decreased rapidly from 100 ka to the present value. This peak in size in the middle of the life of this species indicates a non-monotonic evolutionary pattern. Because this peak is synchronous with a maximum eccentricity in this time period, we conclude that this pattern supports the hypothesis of an influence of ES cycles on the size evolution of Noelaerhabdaceae.

References

Beaufort, L., Bolton, A.C.T., Sarr, A.-C., Suchéras-Marx, B., Rosenthal, Y., Donnadieu, Y., Barbarin, N., Bova, S., Cornuault, P., Gally, Y., Gray, E., Mazur; J.-C. & Tetard, M. 2022. Cyclic evolution of phytoplankton forced by changes in tropical seasonality. *Nature*, **601**: 79–84.

Bendif, E.M., Nevado, B., Wong, E.L., Hagino, K., Probert, I., Young, J.R., Rickaby, R.E.M. & Filatov, D.A. 2019. Repeated species radiations in the recent evolution of the key marine phytoplankton lineage *Gephyrocapsa*. *Nature Communications*, **10**: 1–9.

How did calcareous nannoplankton respond to palaeoenvironmental-factor changes at low and high latitudes in the Late Aptian–Early Albian interval?

Chiara Bettoni, Cinzia Bottini
Department of Earth Sciences, Università degli Studi di Milano, 20133 Milan, Italy; chiara.bettoni@unimi.it
Jens O. Herrle
Institute of Geosciences, Goethe University Frankfurt, Altenho ¨ferallee 1, D-60438 Frankfurt am Main, Germany

The geological record is characterised by case histories marked by profound changes in the ocean–atmosphere system, such as the injection of a large amount of CO_2, super-greenhouse conditions, oceanic anoxia, increased surface-water fertility, and changes in bio-limiting metal concentrations. To better understanding such ecosystem variations, we study calcareous nannoplankton, which are good palaeoecological tracers, being one of the most important calcifying groups among the marine phytoplankton. Several studies on living coccolithophore species have demonstrated that they are very sensitive to environmental changes (i.e. temperature, nutrient content, CO_2 and trace metal concentration) that could affect their shapes, dimensions and abundances. However, it is still not clear which factors can alter nannofossil size in the long-term, and if there is a different response in the average size of selected species dependent on palaeolatitude.

We studied a 14-Myr-long time interval from the Late Aptian to the Early Albian, which included a cooling event and two oceanic anoxic events—OAE1a and OAE1b. We analysed the variations in abundance and size of selected nannofossil species with affinities to temperature and fertility, such as *Watznaueria barnesiae* (oligotrophic species), *Rhagodiscus asper* (warm water), *Zeugrhabdotus erectus* and *Biscutum constans* (mesotrophic species). Samples were collected from two low-latitude cores—ODP Site 1049 (proto-North Atlantic Ocean) and the Piobbico core (Umbria–Marche, western Tethys Basin, central Italian Apennines)—and from a high-latitude site—DSDP Site 511 (Falkland Plateau, South America).

The morphometric results showed significant dimensional and abundance variations, which followed similar patterns in the three studied sites, albeit with different mean sizes. For Site 511, the results showed that *W. barnesiae* and *B. constans* were larger than the specimens at low latitudes. Also, *B. constans* and *Z. erectus* displayed similar trends in all studied sites, with a size reduction during OAE1a and a small average size from the end of OAE1a up to the end of OAE1b. In addition, the resistant and cosmopolitan species *W. barnesiae*, which commonly does not evidence coccolith size change, showed size variations that differed from those in *B. constans* and *Z. erectus*, possibly suggesting that size was controlled by different palaeoenvironmental factors—whilst the *W. barnesiae* size seems to have depended on temperature, the *B. constans* and *Z. erectus* sizes followed the surface-water fertility. The only exception was the size drop across OAE1a, which affected all studied species, including *R. asper*, probably in response to surface-water acidification.

Silicon in fossil and cultivated coccoliths of *Helicosphaera carteri*: New insights from X-ray fluorescence and infrared spectroscopy analyses

Manuela Bordiga

National Institute of Oceanography & Applied Geophysics OGS, Via Auguste Piccard 54, 34151 Trieste, Italy

Alessandra Gianoncelli, Giovanni Birarda, Simone Pollastri, Valentina Bonanni, Lisa Vaccari, Gianluca Gariani

ELETTRA – Sincrotrone Trieste, Strada Statale 14, km 163.5 in the Area Science Park, I-34012 Trieste–Basovizza, Italy

Diana Eva Bedolla

ELETTRA – Sincrotrone Trieste, Strada Statale 14, km 163.5 in the Area Science Park, I-34012 Trieste–Basovizza, Italy & AREA Science Park, Padriciano 99, 34149 Trieste, Italy

Federica Cerino, Marina Cabrini, Alfred Beran

National Institute of Oceanography & Applied Geophysics OGS, Via Auguste Piccard 54, 34151 Trieste, Italy

Maurizio Zuccotti, Silvia Garagna, Giulia Fiorentino

Department of Biology & Biotechnologies "Lazzaro Spallanzani", University of Pavia, Via Ferrata 9, 27100 Pavia, Italy

Miriam Cobianchi, Claudia Lupi

Department of Earth & Environmental Sciences, University of Pavia, Via Ferrata 1, 27100 Pavia, Italy

Coccolithophores, one of the main marine calcifiers, have significantly impacted atmosphere–ocean CO_2 exchanges and the global carbon cycle through geological time by capturing CO_2 through photosynthesis and permanently fixing carbon in their coccospheres, which are composed of micrometrical carbonate plates (i.e. coccoliths). However, the physiology and proliferation strategies of coccolithophores are still poorly known, especially at the species-specific level. Recent studies on DNA sequences have proved that some living species need silica transporters (SITs) or silica-like transporters (SILTs) to build coccoliths. To date SITs and SILTs have been identified in only a few species, such as *Coccolithus braarudii*, *Calcidiscus leptoporus*, *Prymnesium neolepis* and *Scyphosphaera apsteinii*, whereas the species belonging to the Isochrysidales, such as *Emiliania huxleyi* and *Gephyrocapsa oceanica*, do not record the presence of either SITs or SILTs.

A deeper knowledge of silicon (Si)-requiring species is important for understanding their physiology and distribution, as well as the evolutionary steps driving the SIT and SILT strategy. To investigate the presence of Si in coccoliths, we analysed, for the first time, both cultured and fossil coccoliths in three beamlines of the Elettra Sincrotrone Trieste: 1) hard X-ray fluorescence (XRF); 2) soft X-ray microscopy and low-energy X-ray fluorescence (TwinMic); and 3) infrared spectroscopy (SISSI). We selected the species *Helicosphaera carteri* because: 1) it is heavily-calcified; 2) its large coccoliths made picking of the specimens easier; and 3) it belongs to the order Zygodiscales, which contains only one species containing SILTs. Species-specific fossil coccoliths were picked, using a micromanipulator, from two deep-sea sediment samples from the NW Pacific (Ocean Drilling Program Site 1209) and deposited during Marine Isotope Stage (MIS) 5, which is considered to be a good analogue for modern warming, and during the previous glacial phase, MIS 6. To dispel any bias derived from fossilisation processes, we also analysed single coccoliths extracted from monospecific cultures of *H. carteri* grown under 290 ppm of CO_2 to mimic the conditions recorded during MIS 5.

Thanks to these newly applied methodologies, we present preliminary results that show the presence of Si in both the cultured and fossil *H. carteri* coccoliths. More specifically, the XRF beamline detected Si in the cultured sample at the macro-scale, whereas the TwinMic microscope returned Si distribution maps for single coccoliths at the sub-micrometric scale. The SISSI beamline provided semi-quantitative data on the $CaCO_3$ and Si content. Combining these multi-beamline and multi-technique data, we documented higher Si contents in the cultured samples than in the fossil samples,

possibly due to preservational issues. Our data revealed the potentiality of the XRF, TwinMic and SISSI beamlines in analysing the chemical composition of the inspected samples, both at the elemental and molecular scales, in both cultured and fossil coccoliths at the species level. This is pivotal in coccolithophore studies because monospecific elemental analyses in the fossil record are extremely complex, if not almost impossible. This research was funded through MUR for ECORD–IODP Italia.

Calcareous nannoplankton as a useful tool in coastal dynamics and (palaeo)environments

Mário Cachão
Faculty of Sciences & Instituto Dom Luiz, University of Lisbon, Campo Grande, 1749-016 Lisboa, Portugal; mcachao@fc.ul.pt

The sedimentological record of the calcareous nannoplankton is mainly studied in the oceanic domain where it occurs with maximal abundances and diversity. However, for some time now, we have also been using its record as a tracer of the marine influence on coastal systems, such as rias, estuaries and coastal lagoons. Examples range from storm or tsunamigenic deposits to sea-level-induced palaeoenvironmental changes.

Here, I present preliminary results from a new protocol for sampling sandy shores and quantifying their calcareous nannoplankton and other coastal groups, such as ascidian (aragonite spicule taxa) and calcareous macroalgal (micron-sized cell-wall fragments known as tubiliths) taphocoenoses. Still in the validation stage, this protocol uses a design of three replicates: 1) three beaches to characterise each coastal sector; 2) three samples to characterise each beach; and 3) three scans to characterise each smear-slide.

Repeated three times throughout 2021 and 2022, this spatially high-resolution study covered three sectors—the open-sea western Iberian Portuguese Atlantic coast (Santa Cruz, Rodízio and Guincho beaches), the outer Tagus Estuary (Cascais, Carcavelos and Algés beaches) and the inner Tagus Estuary (Alcochete, Montijo and Alfeite beaches). The results corroborate the usefulness of calcareous nannoplankton for characterising between these distinct coastal domains.
Acknowledgements: This work was funded by the Portuguese Fundação para a Ciência e a Tecnologia (FCT) IP/MCTES through national funds (PIDDAC) – UIDB/50019/2020.

Effect of nutrient limitation on the calcification of *Gephyrocapsa oceanica* and *Chrysotila roscoffensis*

Alfred Champigny
Department of Earth Sciences, University of Oxford, South Parks Road, OX1 3AN, UK & Université du Littoral Côte d'Opale, Boulogne sur Mer, France; alfred.champigny@etu.univ-littoral.fr
Rosalind E.M. Rickaby
Department of Earth Sciences, University of Oxford, South Parks Road, OX1 3AN, UK

With global warming, it has been shown that the oceans will become more stratified, reducing the vertical supply of nutrients from deeper nutrient-rich waters to the surface. Indeed, these exchanges are very important for all marine plankton, especially in oligotrophic waters. *Emiliania huxleyi* has been described quite well in relation to these conditions, whether it be the life-cycle, calcification or the polysaccharides that govern the calcification. We have examined different species of coccolithophores (*Gephyrocapsa oceanica* and *Chrysotila roscoffensis*) under nutrient limitation to determine whether there is a common response, particularly with regard to their ability to produce calcite, for the entire group or whether responses differ among species. For *E. huxleyi*, it has been shown that calcification is enhanced, specifically with an increase in the number of coccoliths produced and an increase in coccolith size, together with a decrease in growth rate.

Experiments were carried out using semi-continuous batch cultures with reduced N and P availability in the laboratory. Many parameters were studied, such as growth rate, cell size, and coccosphere and coccolith diameter, in order to better understand whether significant differences are present in the life-cycle of the cells. In addition, we calculated the calcite production per day and per cell under each condition, which allowed us, for the first time, to calculate production rates (ng $cell^{-1}$ day^{-1}) for these species under phosphate and nitrate limitation. Production values (mg day^{-1}) in our cultures allowed us to understand how the production rates of calcite may evolve at the community scale in response to nutrient depletion. In particular, we explored whether there is a trade-off between growth rate and calcification rate, such that slower-growing communities may still produce the same amount of calcite even when the calcite/cell may be increased. We also explored how the morphometry of the coccoliths changed, which may help in identifying nutrient limitation in fossil coccoliths in sediments. Finally, this research will help us to better understand how coccolithophorids and their calcification acclimatise under nutrient limitation.

Early to Middle Jurassic calcareous nannofossil biostratigraphy: A preliminary scheme for south-western Gondwana

Micaela Chaumeil-Rodríguez
CONICET – División Científica de Geología, Museo de La Plata, Paseo del Bosque s/n, La Plata 1900, Argentina & Université Lyon, UCBL, ENSL, UJM, CNRS, LGL-TPE, 69622, Villeurbanne 69100, France; micachaumeil@gmail.com

Emanuela Mattioli
Univ Lyon, UCBL, ENSL, UJM, CNRS, LGL-TPE, 69622, Villeurbanne 69100, France & Institut Universitaire de France, Paris, France; emanuela.mattioli@univ-lyon1.fr

Juan Pablo Pérez Panera
CONICET – División Científica de Geología, Museo de La Plata, Paseo del Bosque s/n, La Plata 1900, Argentina

Biostratigraphic studies on Early to Middle Jurassic calcareous nannofossils from the south-eastern Pacific Ocean are scarce and a local biostratigraphic scheme has not been developed yet. We present here the calcareous nannofossil assemblages from the El Matuasto outcrop sections (I, II and III) in the Los Molles Formation, Neuquén Basin (Argentina), dated as Lower Pliensbachian (NJT4) to Lower Bajocian (NJT9), according to the zonal markers of the Tethyan scheme by Ferreira et al. (2019). The assemblages showed a high diversity index and good preservation, allowing us to analyse the evolution of the group, from the local to global scales.

The Pliensbachian succession was characterised by *Calyculus* sp., *Crepidolithus granulatus*, *C. crassus*, *Parhabdolithus liasicus*, *Similiscutum cruciulus* group, *S. finchii*, *S. giganteum*, *Tubirhabdus patulus* and the first occurrences (FOs) of *Crepidolithus pliensbachensis*, *Biscutum grande*, *Lotharingius barozii*, *Parhabdolithus robustus* and *Lotharingius hauffii*. The Toarcian was characterised by *Axopodorhabdus atavus*, *Biscutum dubium*, *L. hauffii*, *Orthogonoides hamiltoniae*, *S. cruciulus* group, *T. patulus* and the FOs of *Zeugrhabdotus erectus*, *Carinolithus superbus*, *Watznaueria fossacincta*, *Discorhabdus striatus*, *D. criotus*, *Retecapsa incompta* and *Watznaueria contracta*. The Aalenian association was characterised by *Biscutum intermedium*, *C. superbus*, *Calyculus* sp., *Discorhabdus* sp., *Ethmorhabdus* sp., *Lotharingius barozii*, *L. hauffii*, *L. sigillatus*, *Podorhabdus grassei*, *Similiscutum novum*, *Triscutum sullivanii*, *Watznaueria contracta*, *Zeugrhabdotus erectus* and the FO of *Watznaueria britannica*. The Early Bajocian contained the presence of *B. intermedium*, *Discorhabdus* sp., *Ethmorhabdus* sp., *L. hauffii*, *L. sigillatus*, *P. grassei*, *R. incompta*, *S. novum*, *W. britannica*, *W. contracta*, *W. fossacincta* and *Zeugrhabdotus erectus*, with the last occurrence of *Calyculus* sp.

The calcareous nannofossils reported in this contribution constitute the most time-expanded and continuous record of the group in the Neuquén Basin and south-western Gondwana. The assemblage composition has many similarities with western Tethys assemblages, but some discrepancies also occur, mainly in the FOs of some species. This deserves to be further explored and a local biozonation scheme for the area should be established.

Isolating and analysing the coccolith size fraction as a metric for diagenesis

Shamar C. Chin
Department of Earth & Environmental Sciences, 115 Trowbridge Hall, University of Iowa, Iowa City, 52242 Iowa, USA; shamar-chin@uiowa.edu
David K. Watkins
Department of Earth and Atmospheric Sciences, University of Nebraska, Lincoln, 68588 Nebraska, USA
John A. Sarao
Department of Geology and Geophysics, 157 New Halbouty Hall, Texas A&M University, College Station, 77843 Texas, USA
Chelsea M. Bouslog, Samantha N. Eberly
Department of Earth & Environmental Sciences, 115 Trowbridge Hall, University of Iowa, Iowa City, 52242 Iowa, USA

Deriving palaeotemperatures using calcareous nannofossils presents challenges because of their size and diagenetic overprint. An example is the cool-tropics paradox, which concluded that high-resolution imaging might not detect the microscopic recrystallisation of calcite, posing a problem when analysing and interpreting the primary signal for palaeo-sea-surface temperatures. In order to develop more precise analyses for calcareous nannofossils as a palaeotemperature proxy, it is necessary to continue exploring and refining methods for isolating the coccolith-sized fraction. In addition, these methods will improve upon techniques used for picking individual coccoliths for high-lateral-resolution analyses. In assessing primary temperature signals, studies have shown that, as the coccolith-sized fraction decreases in size, temperatures also decrease. As a result, there is a need to recalibrate the metrics to determine the extent of diagenetic alteration and the calculations for palaeotemperatures. Given these caveats, this study aimed to develop a cost-effective method for assessing diagenesis in coccolith-rich sediments. Samples from the uppermost Albian–Lower Cenomanian of the North Atlantic Ocean (Deep Sea Drilling Project Leg 79, Site 547) were used for centrifugation. The samples were primarily nannofossil-bearing clays with moderately to well-preserved calcareous nannofossils. Using a surfactant, ultrasonication, centrifugation and decanting, the rotations per minute and speed were altered until a fine-grained fraction, a coccolith-sized fraction and a coarse-grained fraction were produced. The integrity of the calcareous nannofossil assemblages was determined by comparing counts from the bulk sediment samples to those of the coccolith-sized fraction. Using ImageJ, the mean areas of the grains were calculated for the fine-grained fraction (0.073 μm^2), the coccolith-sized fraction (1.627 μm^2) and the coarse-grained fraction (3.5366 μm^2).

After separating the distinct size fractions from an interval with well-preserved calcareous nannofossils, the coccolith-sized fraction and bulk sediment samples were analysed for $\delta^{13}C$ and $\delta^{18}O$ to assess the effectiveness of the proposed centrifugation method. The $\delta^{13}C$ values of the coccolith-sized fraction and bulk sediment had similar trends and a significant positive correlation. However, the $\delta^{18}O$ values for the coccolith-sized fraction and bulk sediments did not have a significant correlation. Furthermore, a significant decoupling of the $\delta^{18}O$ curves occurred at the Albian–Cenomanian boundary and terminated in the lowermost Cenomanian. The $\delta^{18}O$ values for the bulk sediment samples were characterised by a positive $\delta^{18}O$ excursion throughout this interval, indicating lower temperatures when compared to the coccolith-sized fraction. A plausible cause for the deviation in $\delta^{18}O$ values could be diagenesis—a significant amount of dolomite rhombs in the bulk sediment samples supports this hypothesis. By contrast, centrifugation removed a significant portion of the dolomite rhombs from the coccolith-sized fraction. Given these caveats, this method can be used to aid with estimating the extent of diagenesis. It is also important to note that the $\delta^{13}C$ values were likely similar due to low organic-matter concentrations throughout this section. Therefore, the amount of organic matter should be factored into any isotopic analysis. Based on these preliminary results, we conclude that isotopic analyses of the isolated coccolith-sized fraction could be a potential metric for identifying diagenesis. Furthermore, this cost-effective method does not require extensive sample preparation, and the parameters can be modified to account for different lithologies and grain sizes.

Eocene calcareous nannofossils from the Humor Basin (Eastern Carpathians, Romania): Biostratigraphy and palaeoenvironmental reconstruction

Carmen Mariana Chira, Raluca Bindiu-Haitonic

Babeş-Bolyai University, Department of Geology & Research Centre for Integrated Geological Studies, 1 Mihail Kogălniceanu Street, 400084 Cluj-Napoca, Romania; carmen.chira@ubbcluj.ro

The Rea Valley section in the Tarcău Nappe, which belongs to the Carpathian flysch, was analysed in order to integrate biostratigraphical, sedimentological and palaeoecological data. The studied section was located between Humor Monastery and Poiana Micului village, and consisted of siliciclastic turbidites characteristic of deep-water deposition. The calcareous nannofossils assemblages were quantitatively and qualitatively analysed. The studied samples were collected from fine-grained intercalations in the turbiditic sequence, at an interval of about 50 cm from each other. For analysis of the calcareous nannofossil assemblages, the samples were processed using two different standard micropalaeontological methods. Samples for the smaller foraminifera were processed following the classical method. The abundances of calcareous nannofossils and foraminifera displayed variations through the section. Most samples contained abundant microfossils, although a few were almost barren.

The calcareous nannofossil assemblages were generally rich in reticulofenestrids (reaching up to 80% in the basal part of the section), such as *Reticulofenestra umbilicus* (NP16—Lutetian to NP22—Rupelian), *R. dictyoda*, *R. reticulata*, *R. bisecta* and *R. minuta*. *Zygrhablithus bijugatus* (NP9—Thanetian to NN1—Aquitanian), *Discoaster lodoensis* (NP12—Ypresian to NP14—Lutetian), *D. saipanensis* (NP14—Ypresian to NP19–20—Priabonian) were also present in the analysed samples (but not exceeding 5%). The assemblages also contained (in low percentages) *Chiasmolithus gigas*, *Pontosphaera pulchra*, *Pontosphaera* sp., *Coccolithus pelagicus*, *C. eopelagicus*, *Helicosphaera bramlettei* (NP14—Ypresian to NP25—Chattian), *Helicosphaera carteri*, *Sphenolithus anarrhopus*, *S. moriformis*, *S. furcatolithoides* (Lutetian–Bartonian), *Lanternithus minutus*, *Neococcolithes* sp., *Braarudosphaera bigelowii*, calcispheres and ascidian spicules.

The foraminiferal assemblages were composed of coarsely agglutinated individuals with a moderate to good degree of preservation. Typical deep-water agglutinated foraminifera, together with *Ammolagena clavata*, indicated bathyal deposition. The calcareous nannofossil assemblages and smaller benthic foraminifera placed the deposits in the Middle Eocene (NP17—*Discoaster saipanensis* Zone) of the Sucevița Formation. The palaeoecological information, based on statistical interpretations (i.e. of diversity indices, abundances, clusters), suggested relatively favourable conditions in the water-column.

The distribution of the calcareous nannofossil and foraminifera assemblages provided important criteria for facies correlation and allowed a reconstruction of the regional evolution of the Humor Basin (northern Eastern Carpathians, Romania).

The mesostructural evolution of *Nannoconus* via ptychographic X-ray computed tomography

Rajkumar Chowdhury, Fabienne Giraud, Alejandro Fernandez-Martinez
Université Grenoble Alpes, Université Savoie Mont Blanc, CNRS, IRD, IFSTTAR, ISTerre, 38000 Grenoble, France; rajkumar.chowdhury@univ-grenoble-alpes.fr

Julio Cesar da Silva, Redhouane Boudjehem, Anico Kulow
Université Grenoble Alpes, CNRS, Grenoble INP*, Institut Néel, 38000 Grenoble, France

Baptiste Suchéras-Marx
Aix Marseille University, CNRS, IRD, INRAE, CEREGE, Aix-en-Provence, France

Gaston Garbarino
ESRF, 71 avenue des Martyrs, 38043 Grenoble, France

Jean Louis Hazemann
Université Grenoble Alpes, CNRS, Grenoble INP*, Institut Néel, 38000 Grenoble, France

Javier Perez
SWING Beamline, Synchrotron SOLEIL, L'Orme des Merisiers, BP48, Saint-Aubin, Gif-sur-Yvette, F-91192 France

Among the calcareous nannofossils present in the Early Cretaceous oceans, *Nannoconus* had the largest exoskeleton (5–30 μm) and was the main planktonic carbonate bio-producer. Knowledge of the organism that produced the 3D conical exoskeleton of *Nannoconus* is nonexistent, but a detailed analysis of both the morphology and structure of the exoskeleton can give information about its mode of calcification and palaeobiology. The exoskeleton presents a great variability of plate arrangements, which has allowed the recognition of nine morphogroups that appear successively through the nearly 35 Myr studied and that could explain its success story. Furthermore, turnovers in abundance of the dominant morphogroups were observed, probably associated with environmental changes that may have caused their morphological evolution. The main question driving this study was, has the morphology evolved significantly in adapting to the environment?

To better understand the exoskeleton construction and this variability, there was a need to correlate the *Nannoconus* microstructure at the nanometer scale with the environment. To address this, we used ptychographic X-ray computed tomography (PXCT), which determined the 3D structure of different *Nannoconus* specimens from various ages at the nanometre level (resolution of a few tens of nanometres). The need for high spatial resolution tomography was supported by the small size of the inner structural elements, on the order of ~100 nm thick and a few millimetres long.

Sediment samples containing well-preserved *Nannoconus* spp. were selected from Hole 603B of DSDP Leg 93 and the Munk Marl Formation of the North Sea, ranging from Valanginian (~140 Ma) to Aptian (~113 Ma) in age. A filtration process was applied to the sediment in suspension in order to increase the abundance of *Nannoconus* specimens. Because *Nannoconus* recrystallises easily, the preservation state was verified using both optical and scanning electronic microscopy. Raman microspectroscopy was used to characterise the mineralogy, revealing very pure calcite crystals. Finally, more than 10 of the best-preserved *Nannoconus* specimens were isolated from the sedimentary matrix using picking techniques developed by us. Once isolated, various species of *Nannoconus* were analysed using PXCT at the SWING experimental station of the SOLEIL French synchrotron (June 2022), for evaluating the morphological evolution. Interpretation of the results obtained during this experiment is still in progress and will be presented at the meeting.

Calcareous nannofossils from the Middle/Upper Miocene succession of Pécs–Danitzpuszta (Lake Pannon), southern Hungary

Stjepan Ćorić
Geological Survey of Austria, Neulinggasse 38, 1030 Vienna, Austria; Stjepan.Coric@geologie.ac.at
Mădălina-Elena Kallanxhi
Albanian Geological Survey, Rr. Myslym Keta, Tirana, Albania

Quantitative analyses of calcareous nannofossils were carried out on 109 Middle/Upper Miocene (Sarmatian/Pannonian, Upper Serravallian/Tortonian) samples from the 12–79-m interval of the Pécs–Danitzpuszta sand pit (Hungary). The Danitzpuszta outcrop, located on the eastern outskirts of the city of Pécs, is the largest exposure of Pannonian white marls in Hungary. The sand pit itself exposes Upper Miocene Lake Pannon sediments.

All samples from the Pécs–Danitzpuszta outcrop contained low-diversity calcareous nannofossil assemblages. The section can be divided into three intervals that reflect palaeoecological changes during the Late Sarmatian and Pannonian. Interval 1 is dominated by normal-marine nannofossils, such as *Calcidiscus leptoporus*, *Reticulofenestra pseudoumbilicus*, *Sphenolithus moriformis* and *Syracosphaera* spp., and by didemnid ascidian spicules (from sea squirts). This assemblage points to warm, shallow oligotrophic marine conditions. A slight increase in eutrophication in the upper part was probably caused by enhanced nutrient supply from rivers. Interval 2 displays very low diversity. The co-occurrence of endemic *Praenoelaerhabdus*, and small and normal-marine *Acanthoica cohenii* and *Syracosphaera* spp. indicates a drop in salinity, which can be interpreted as a stepwise transition from marine to brackish lacustrine conditions. The longest interval, Interval 3, is characterised by an alternation of monospecific assemblages with either ascidians (*Perforocalcinella fusiformis*) or *Isolithus* spp. Assemblages dominated by ascidians (*P. fusiformis*) are interpreted as periods of shallowing based on the co-occurrence of diatoms and sponge remains in this interval. Contrastingly, the intervals with abundant *Isolithus* spp. are interpreted as periods of slight deepening. In addition, a short interval with endemic calcareous nannofossils (*Bekelithella echinata*, *Noelaerhabdus* spp.) also indicates a period of deepening in the basin. Changes in the Pannonian assemblages were influenced by changes in the environmental circumstances, most probably water depth and salinity.

Based on the abundance of *R. pseudoumbilicus* and the absence of *S. heteromorphus* and *Cyclicargolithus floridanus*, Intervals 1 and 2 can be attributed to the upper NN6 (and/or NN7) standard nannoplankton zone(s) (younger than 12.1 Ma), and are interpreted here as belonging to the marine Late Sarmatian, whereas Interval 3 correlates with the brackish lacustrine Pannonian. Based on the occurrences of *B. echinata* and species belonging to the genus *Noelaerhabdus*, the upper part of the section was attributed to NN10. Our investigations show that the quantitative assessment of endemic calcareous nannofossils might be a tool for stratigraphic correlation in the Pannonian. The applied statistical methods document the response of nannofossil assemblages to the rapid environmental and palaeoecological changes that took place during the Sarmatian and Pannonian (Upper Serravallian and Tortonian) in this part of the Pannonian Basin.

The effects of pelagic carbonate production on the Pleistocene carbon cycle

Josué Dauvier, Luc Beaufort, Laurence Vidal
Aix-Marseille University, CNRS, IRD, INRAE, CEREGE, Aix-en-Provence, France; beaufort@cerege.fr

The role of climate in biological evolution has often been documented, but the reverse is much more rare. In this study, we tried to see if the evolution of coccolithophores could have influenced the marine carbon cycle ($CaCO_3$ production and carbon isotopes). To do so, we studied a core collected off Tanzania, measuring stable carbon and oxygen isotopes in planktonic foraminifera and the fine fraction (<30 μm), and coccolithophore-related parameters (assemblages determined by taxon in number, mass and morphology). A morphological diversity index (MDI), recently used to quantify the evolution of the Noelaerhabdaceae, covaried significantly with coccolith mass fluxes and the stable carbon isotopes. The MDI was very close to the recently published one. We show that the evolution of coccolithophores can vary with the fine fraction $\delta^{13}C$ and the carbonate content in sediments, and thus is part of the oceanic carbon cycle.

The Paleocene/Eocene boundary and emendation of the NP9/NP10 zonal boundary of Martini (1971)

Eric de Kaenel
DPR, Chemin sous la Roche 4b, 1185 Mont-sur-Rolle, Switzerland; edekaenel@bluewin.ch
David Bord
Ellington Geological Services, 1414 Lumpkin Road, Houston, Texas 77043, USA
James J. Pospichal
BugWare Inc., 1615 Village Square Blvd, Ste. 8, Tallahassee, Florida 32309, USA

The reference section for the Paleocene/Eocene global boundary stratotype section and point (GSSP) is the Dababiya Quarry near Luxor in Egypt. This section is considered to be the most complete Upper Paleocene to Lower Eocene sequence representative of this boundary, with a 2.83 m Paleocene–Eocene Thermal Maximum (PETM) interval (core and Recovery Phase I intervals, according to Röhl et al., 2007). A new analysis of this section, based on 56 samples, was undertaken in 2022. The samples were collected at 2, 5 and 10 cm intervals by Khozyem et al. (2014). These were processed for calcareous nannofossils and prepared on glass slides according to the settling technique described in De Kaenel & Villa (1996). The preservation of the nannofossils was exceptionally good, except for in a 52-cm-thick dissolution interval (devoid of nannofossils) at the base of the PETM. The nannofossil simple diversity varied between 50 and 123 species below and above the barren interval. A total of 180 species were identified from the Upper Paleocene to Lower Eocene. No reworking was observed.

According to the standard nannofossil zonation of Martini (1971), the NP9/NP10 boundary is placed at the lowest occurrence (LO) of *Tribrachiatus bramlettei* and is usually used to approximate the Paleocene/Eocene boundary. Determining the exact position of the LO of *T. bramlettei* is problematic, however, because of the difficulties in distinguishing specimens of the genus *Tribrachiatus* (a triradiate structure superimposed on another trigonal structure) from those of the genus *Rhomboaster* (a cubic/rhombohedral form, albeit a flattened or misshapen one) at the top of the PETM core/base Recovery Phase I intervals. Detailed observations of the structure and geometry of the inter-arm regions between the spines were used here to distinguish between these two genera, but this also did not allow for a precise placement of the NP9/NP10 boundary.

In the literature, the NP9/NP10 boundary has been placed within the PETM interval (e.g. Menini et al., 2022), at the base of the genus *Rhomboaster* (e.g. Bybell & Self-Trail, 1997) or well above the PETM interval (Aubry et al., 2000). These discrepancies are related to the position of the LO of *T. bramlettei* and the individual workers' method for making (or not making) a distinction between it and *Rhomboaster*. In the Dababiya section, we observed the LO of the genus *Rhomboaster* (the small cubic *R. cuspis*) at the base of the negative carbon isotope excursion (NCIE), and therefore at the Paleocene/Eocene boundary, and the LO of the genus *Tribrachiatus* at the top of the NCIE. In order to clarify the position of the NP9/NP10 boundary, the following changes to the standard nannofossil zonation of Martini (1971) are proposed:

NP9 – *Discoaster multiradiatus* Zone, emended
Definition: Interval from the LO (base) of *Discoaster multiradiatus* to the LO (base) of the genus *Rhomboaster*.
Authors: Bramlette & Sullivan (1961), emended de Kaenel, Bord & Pospichal.
NP10 – *Tribrachiatus contortus* Zone, emended
Definition: Interval from the LO (base) of the genus *Rhomboaster* to the LO (base) of *Tribrachiatus contortus*.
Authors: Hay (1964), emended de Kaenel, Bord & Pospichal.

These emendations will resolve the discrepancies around the position of the NP9/NP10 boundary and provide consistency for biostratigraphers working on the PETM interval. This boundary will be easier to recognise and would unify the stage and biozone boundaries.

References

Aubry, M.-P., Cramer, B.S., Miller, K.G., Wright, J.D., Kent, D.V. & Olsson, R.K. 2000. Late Paleocene Event chronology: Unconformities, not diachrony. *Bulletin de la Société Géologique de France*, **171**(3): 367–378.

Bramlette, M.N. & Sullivan, F.R. 1961. Coccolithophorids and related nannoplankton of the Early Tertiary in California. *Micropaleontology*, **1**: 129–74.

Bybell, L.M. & Self-Trail, J.M. 1997. Late Paleocene and Early Eocene calcareous nannofossils from three boreholes in an onshore–offshore transect from New Jersey to the Atlantic continental rise. *In*: K.G. Miller & S.W. Snyder (Eds.). *Proceedings of the ODP, Scientific Results*, **150X**: 91–110.

de Kaenel, E. & Villa, G. 1996. Oligocene–Miocene calcareous nannofossil biostratigraphy and paleoecology from the Iberia Abyssal Plain. *In*: R.B. Whitmarsh, D.S. Sawyer, A. Klaus & D.G. Masson (Eds.). *Proceedings of the ODP, Scientific Results*, **149**: 79–145.

Hay, W.W. 1964. Utilisation stratigraphique des Discoastérides pour la zonation du Paléocène et l'Eocène inférieur. *Mémoires du Bureau Recherches Géologiques et Minières*, **28**(2): 885–889.

Khozyem, H., Adatte, T., Keller, G., Tantawy, A.A. & Spangenberg, J.E. 2014. The Palaeocene–Eocene GSSP at Dababiya, Egypt—Revisited. *Episodes*, **37**(2): 78–86.

Martini, E. 1971. Standard Tertiary and Quaternary calcareous nannoplankton zonation. *In*: A. Farinacci (Ed.). *Proceedings of the Second Planktonic Conference, Roma 1970. Edizioni Tecnoscienza Rome*, **2**: 739–785.

Menini, A., Mattioli, E., Vinçon-Laugier, A. & Suan, G. 2022. Calcareous nannofossil biostratigraphy across the Paleocene–Eocene Thermal Maximum. *Newsletters on Stratigraphy*, **55**(1): 69–97.

Röhl, U., Westerhold, T., Bralower, T.J. & Zachos, J.C. 2007. On the duration of the Paleocene–Eocene Thermal Maximum (PETM). *Geochemistry, Geophysics, Geosystems*, **8**: Q12002.

Early evolution of calcareous nannofossils in the Late Triassic in the Neo- and Palaeo-Tethys Oceans

Isaline Demangel, Sylvain Richoz
Department of Geology, Lund University, Sweden; isaline.demangel@geol.lu.se
Silvia Gardin
Center for Research on Palaeobiodiversity & Palaeoenvironments, Sorbonne University, Place Jussieu, 4, 75252 Paris, France
Eugen Grădinaru
Department of Geology, Faculty of Geology & Geophysics, University of Bucharest, Romania

The evolutionary appearance of the calcareous nannofossils, and especially coccolithophorids, has been the focus of several studies, with the oldest coccoliths having been reported from the Rhaetian. This project focused on the early calcareous nannoplankton from the Late Triassic (Norian–Rhaetian, 227–201.3 Ma) with the aim of understanding their impact on ocean chemistry during this time. We investigated their emergence and evolution, in terms of their abundance and spread across different latitudes and environments. The sediments analysed covered different palaeolatitudes, with sections from the western and southern Neo-Tethys Ocean, as well as from the Palaeo-Tethys Ocean, where no calcareous nannofossils have previously been recorded. To tackle the problems of diagenesis and poor preservation that have often impacted Upper Triassic sediments and the calcareous nannofossils in them, we used different methodologies depending on the lithology. Both soft and hard calcareous lithologies were analysed directly using a scanning electron microscope, with the soft lithologies also being investigated in standard smear-slides observed using a light microscope. Our study reports on the first coccoliths—not identified to the species level—from the Middle Norian (Alaunian 3, ~215 Ma). The oldest coccolith species identified was *Crucirhabdus minutus*, observed in the Upper Norian (Sevatian), followed by *Archaeozygodiscus koessenensis*. The first *Crucirhabdus primulus* was found in the Lower Rhaetian. These occurrences suggest that *C. minutus* was the ancestor of the coccolithophorids and that there was a slow evolution over time. *Crucirhabdus primulus* occurred ~4.2 Myr after the ancestral *C. minutus*, with the evolution of a new genus—*Archaeozygodiscus,* represented by *A. koessenensis*—taking around 0.35 Myr. Detailed microscopic investigations have detected two different inner structures in the conical Rhaetian forms belonging to *Eoconusphaera*. Based on this, a new species—*E. hallstattensis*—has been described and *E. zlambachensis* was emended. In the western Tethys, these two species represent new biostratigraphic markers for the Rhaetian, having short and well-defined occurrences. The *Eoconusphaera* species present some similar characteristics to other conical Mesozoic forms, such as *Mitrolithus*, *Calcivascularis* and *Conusphaera*, all now classified as coccoliths. Throughout the Rhaetian, *Prinsiosphaera triassica* was affected by biological and environmental stress conditions. First, with the occurrence of the Eoconusphaeraceae introducing competition for resources, and second, palaeoenvironmental changes that altered its calcification potential, leading to a size decrease from the Early Rhaetian. These two species—*P. triassica* and *E. zlambachensis*—have been observed for the first time in Romanian sections (northern Dobrogea), which were located in the Palaeo-Tethys Ocean during the Late Triassic. They occur commonly, where present.

In the Upper Triassic, calcareous nannofossils have been observed in both hemispheres, but are restricted to shallow and proximal environments. The *incertae sedis P. triassica* dominates assemblages throughout the Upper Triassic, whereas the coccolithophores increase slightly in abundance during the Lower and Middle Rhaetian, reaching a maximum abundance in the Upper Rhaetian. However, a comparison between the quantitative data and calcium isotope measurements does not provide any evidence for a significant influence of these calcifiers on the geochemical composition of the western Neo-Tethys Ocean.

Morphometric changes in the genus *Watznaueria* in the Toarcian–Aalenian: Implications for taxonomy, biostratigraphy and evolution

Elisabetta Erba, Stefano Visentin, Giulia Faucher
Department of Earth Sciences, University of Milan, Milan, Italy; elisabetta.erba@unimi.it

We conducted a morphometric investigation of the genus *Watznaueria* in a Lower–Middle Jurassic pelagic section from the Lombardy Basin (western Tethys Ocean), where a continuous and complete succession crops out at Colle di Sogno, with no evidence of siliciclastic or bioclastic input. In the evolutionary history of calcareous nannoplankton, the Toarcian–Bajocian interval is particularly crucial because this was the time of the emergence and early diversification of the genus *Watznaueria*. Biomorphometric analyses were performed on the species *W. colacicchii*, *W. contracta* and *W. britannica*. In the studied interval, along with specimens unequivocally attributable to these individual species, several specimens appeared to be similar, but with some characters not corresponding to the diagnostic features as described in the formal species definitions. Morphometric analyses were conducted on images taken using a Q imaging Micropublisher 5.0 RTV digital camera mounted on a Leitz Laborlux optical polarising microscope, at 1250x magnification. The images were analysed using a PC with Q-capture Pro suite software adapted for nannofossil analysis. Measurements were taken using ImageJ software, with an error of ±0.08 μm.

Regardless of the size of the coccolith and of the central area, the parameter that unequivocally allows the separation of *W. colacicchii* from *W. contracta* is the coccolith width (W)/central-area width (w) ratio. The W/w ratio remained unchanged stratigraphically, allowing the unambiguous identification of the first occurrences of the two taxa. In the Colle di Sogno section, several *W. britannica* specimens were smaller, thinner and more elliptical than the holotype. In the literature, a wide range of coccolith lengths and widths, and a variety of morphologies of the bridge spanning the central-area, have been described. Our data showed a progressive increase in the coccolith size and a relative decrease in ellipticity. We identified as *W. britannica* only those specimens fully consistent with the formal definition of the species, while separating out a *W.* aff. *W. britannica* group comprising all specimens with different features. In addition, a new species was determined based on a peculiar and diagnostic bridge spanning the central area.

The revised morphometry-based taxonomy allowed us to determine the *Watznaueria* biohorizons and revise the early evolution of the genus. Through the Toarcian–Lower Bajocian interval, *Watznaueria* showed a progressive increase in size and in the W/w ratio, the latter due to shrinkage of the central-area. The structures in the central-area displayed a gradual change, from a cross to a two-button bridge to a single-button bridge, along with a tendency towards an increasingly more closed central-area.

Burning experiments on calcareous nannofossils: Contribution to a better understanding of historic mortar production

Janina Falkenberg, Joerg Mutterlose

Institute of Geology, Mineralogy & Geophysics, Ruhr-Universität Bochum, Universitätsstraße 150, 44801 Bochum, Germany; janina.falkenberg@rub.de

Lime-based mortars consist of lime, which is produced by burning naturally occurring limestones. The limestones are heated to ~900ºC. The burning causes the thermal decomposition of $CaCO_3$ into CaO (i.e. quicklime) and CO_2. The very reactive quicklime is slaked with water, producing $Ca(OH)_2$ (i.e. lime). In a last step, lime reacts with CO_2 in the atmosphere, forming solid $CaCO_3$ again. Calcareous nanno- and microfossils are not expected to be present in lime binders in mortars because of the high heating temperature. Unexpectedly, however, we have encountered the remains of calcareous nannofossils in historic mortars and mortar-based materials.

To gain a better understanding of the behaviour of calcareous nannofossils during the burning procedure, four samples were heated to nine temperature levels (100, 300, 500, 600, 700, 750, 800, 850 and 900ºC). Both, original and heated samples were analysed with respect to their nannofossil contents and preservation using settling slides. Our results showed a decrease in absolute numbers and preservation from 500ºC upwards, but nannofossils were preserved up to 900ºC. Changes in the relative abundances of individual species showed that some taxa were more resistant to heat than others. This pattern is best explained by their different crystal sizes and forms, as well as their surface areas. Calcareous nannofossil abundances, their preservation and the presence/absence of different nannofossil taxa can therefore be used to estimate the burning temperature during quicklime production.

Our study provides a better understanding of historic mortar production, and also supplies information for the preservation of monuments because new mortars can be made with the same material and under the same conditions as those in the past.

How do new phytoplankton species form in the open ocean?

Dmitry A. Filatov
Department of Plant Sciences, University of Oxford, South Parks Road, Oxford OX1 3AN, UK; dmitry.filatov@plants.ox.ac.uk
El Mahdi Bendif, Odysseas A. Archontikis
Department of Earth Science, University of Oxford, South Parks Road, Oxford OX1 3AN, UK
Kyoko Hagino
Center for Advanced Marine Core Research, Kochi University, Monobe B-200, Nankoku, Japan
Rosalind E. M. Rickaby
Department of Earth Science, University of Oxford, South Parks Road, Oxford OX1 3AN, UK

Evolutionary genetic processes underpinning the speciation process in marine phytoplankton are not well understood. Population size is a key parameter in evolutionary genetics, but evolution may work in rather different ways in relatively small populations of terrestrial organisms and astronomically large populations of marine plankton. According to population genetics theory, natural selection works more efficiently in large populations. Thus, the adaptation process is expected to be very efficient in large populations, such as those found in the marine microplankton, and we may expect the classic adaptation-driven Darwinian speciation scenario to play a major role in the evolution of new species in the marine microplankton. However, our evolutionary genetic analysis of genome-wide DNA polymorphism data for five species in the coccolithophore genus *Gephyrocapsa* (including *Emiliania huxleyi*) revealed the opposite trend––a predominance of speciation driven by extrinsic barriers to gene flow rather than the gradual evolution of intrinsic genetic species incompatibilities expected under the Darwinian speciation scenario. The best-fitting scenario for all speciation events analysed includes an extended period of complete genetic isolation followed by recent (last 14 kyr) secondary contact. This model supports the role of geographic or oceanographic barriers in population divergence and speciation. The coincidence of species emergence with glacial inceptions suggests stronger isolation of the ocean basins and increased segregation of low-latitude ecological niches during glaciations being important drivers of isolation and speciation in the marine phytoplankton. The similarity across multiple speciation events implies the generality of this inferred speciation scenario for marine phytoplankton.

Nannofossil response to the Late Oligocene warming event at ODP Site 929 (Ceara Rise, western equatorial Atlantic Ocean)

Chiara Fioroni
Dipartimento di Scienze Chimiche e Geologiche, Università degli Studi di Modena e Reggio Emilia, Via Campi, 103, 41125 Modena, Italy; chiara.fioroni@unimore.it

Isabella Raffi
Dipartimento di Ingegneria e Geologia, Università degli Studi "G. d'Annunzio" di Chieti-Pescara, Campus Universitario, via dei Vestini 31, 66013 Chieti Scalo, Italy

Davide Persico, Giuliana Villa
Dipartimento di Scienze chimiche della vita e della sostenibilità ambientale (SCVSA), Università degli Studi di Parma, Plesso di Scienze della Terra, Parco Area delle Scienze 157A, 43100 Parma, Italy

The Late Oligocene Warming Event (Zachos et al., 2001; Zhang et al., 2013), occurring between ~26.5 and 24 Ma, is still a poorly known climatic change, identified first by deep-sea oxygen isotope data (Zachos et al., 2001; Pekar et al., 2006), and then recognised in the fossil record in a number of settings, both terrestrial (e.g. Wu et al., 2018) and marine (e.g. van Simaeys et al., 2004; Villa & Persico, 2006; Alegret et al., 2008; Villa et al., 2014). It is characterised by an inverse correlation between sea-surface temperature and pCO_2, following cooling due to the Antarctic glaciation during the Eocene–Oligocene transition. Proxy data indicate a period of warming and/or deglaciation during the Late Oligocene, associated with declining pCO_2 (Zhang et al., 2013; O'Brien et al., 2020). In this work, we investigated the response of calcareous nannofossils to this climatic event at ODP Site 929 (Ceara Rise, equatorial Atlantic Ocean), through a high-resolution sample set. We first developed a high-resolution biostratigraphic framework of the considered time interval, then quantitatively defined the palaeoecological preferences of selected species, comparing their general trends with those defined in other oceanographic settings, allowing the main assemblage variation to be correlated with the multi-proxy surface-temperature record recently determined at ODP Site 929 for the Late Oligocene (O'Brien et al., 2020).

References

Alegret, L., Cruz, L.E., Fenero, R., Molina, E., Ortiz, S. & Thomas, E. 2008. Effects of the Oligocene climatic events on the foraminiferal record from Fuente Caldera section (Spain, western Tethys). *Palaeogeography, Palaeoclimatology, Palaeoecology*, **269**: 94–102.

O'Brien, C., Huber, M., Thomas, E., Pagani, M., Super, J.R., Elder, L.E. & Hull, P.M. 2020. The enigma of Oligocene climate and global surface temperature evolution. *Proceedings of the National Academy of Sciences*, **117**: 41.

Pekar, S.F., DeConto, R.M. & Harwood D.M. 2006. Resolving a Late Oligocene conundrum: Deep-sea warming and Antarctic glaciation. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **231**: 29–40.

Van Simaeys, S., De Man, E., Vandenberghe, N., Brinkhuis, H. & Steurbaut, E. 2004. Stratigraphic and palaeoenvironmental analysis of the Rupelian–Chattian transition in the type region: Evidence from dinoflagellate cysts, foraminifera and calcareous nannofossils. *Palaeogeography, Palaeoclimatology, Palaeoecology*, **208**: 31–58.

Villa, G., Fioroni, C., Persico, D., Roberts, A.R. & Florindo, F. 2014. Middle Eocene to Late Oligocene Antarctic glaciation/deglaciation and Southern Ocean productivity. *Paleoceanography*, **29**: 223–237.

Villa, G. & Persico, D. 2006. Late Oligocene climatic changes: Evidence from calcareous nannofossils at Kerguelen Plateau Site 748 (Southern Ocean). *Palaeogeography, Palaeoclimatology, Palaeoecology*, **231**: 110–119.

Wu, F., Miao, Y., Meng, Q., Fang, X. & Sun, J. 2018. Late Oligocene Tibetan Plateau warming and humidity: Evidence from a sporopollen record. *Geochemistry, Geophysics, Geosystems*, **20**: 434–441.

Zachos, J.C., Pagani, M., Sloan, L., Thomas, E. & Billups, K. 2001. Trends, rhythms, and aberrations in global climate 65 Ma to present. *Science*, **292**: 686–693.

Zhang, Y.G., Pagani, M., Liu, Z., Bohaty, S.M. & Deconto, R. 2001. A 40-million-year history of atmospheric CO_2. *Philosophical Transactions of the Royal Society A, Mathematical, Physical and Engineering Sciences*, **371**: 20130096.

Response of marine nannoplankton to environmental forcings: Insights from automated imaging methods on community shifts in the Gulf of Lions over the last decade

Camille Godbillot, Thibault de Garidel-Thoron, Luc Beaufort, Yves Gally
Aix-Marseille Université, CNRS, IRD, INRAE, CEREGE, Aix-en-Provence, France; godbillot@cerege.fr
Karine Leblanc, Cristele Chevalier, Thang D.Q. Le
Institut Méditerranéen d'Océanologie (UMR 7294 MIO), CNRS/Aix-Marseille Université/Université de Toulon/IRD, Marseille, France
Xavier Durrieu de Madron
Centre de Formation et de Recherche sur les Environnements Méditerranéens (UMR 5110 CEFREM), CNRS/Université de Perpignan – Perpignan, France

Recent evidence has shown a decrease in fish catches in the Gulf of Lions synchronous with a decrease in plankton size, raising the question as to the processes involved. The ongoing RapMed project, which involves different laboratories in Aix-Marseille Université, is aimed at providing a better understanding of the variability of planktonic communities and their resilience to environmental changes in this sensitive region. At the base of the food web, diatoms and nannoplanktonic algae are critical in supporting the upper trophic levels. Here, we present the first results of a study initiated in May 2022, which aspired to identify shifts in the micro- and nannoplankton communities, and to review the possible controls on the patterns observed. We apply automated microscope imaging to a decade-long record of calcareous and siliceous nannoplankton shells provided by a sediment-trap series from the Gulf of Lions (MOOSE-LIONCEAU, 42ºN, 5ºE, ~2300 m deep). Using the machine-learning-based workflow of image classification developed as part of the RapMed project, we identified patterns in nannoplankton size and taxonomic community structure over the last decade. The changes detected will be analysed in light of a long-term time-series of environmental variables recorded at the same location.

Isotopic response of Pleistocene coccoliths to an ambient pCO_2 change: A calibration experiment

Camille Godbillot
Institut des Sciences de la Terre de Paris (UMR 7193 ISTeP), CNRS, Sorbonne Université, Paris, France & Aix Marseille Université, CNRS, IRD, INRAE, CEREGE, Aix-en-Provence, France; godbillot@cerege.fr

Fabrice Minoletti
Institut des Sciences de la Terre de Paris (UMR 7193 ISTeP), CNRS, Sorbonne Université, Paris, France

Franck Bassinot
Laboratoire des Sciences du Climat et de l'Environnement (UMR 8212 LSCE), CNRS, CEA, Université Versailles Saint Quentin, Gif sur Yvette, France

Michaël Hermoso
Laboratoire d'Océanologie et de Géosciences (UMR 8187 LOG), CNRS, Université du Littoral Côte d'Opale, Université de Lille, IRD, Wimereux, France

For geological periods where direct measurements of pCO_2 performed on ice cores are not possible, the reconstruction of this key palaeoclimatic parameter can only be achieved through proxy data. Results from both *in vivo* cultures and cell-modelling biogeochemical studies have demonstrated a link between the biological fractionation of coccoliths and the CO_2 concentration of the living environment of their producers—the coccolithophores. Changes in the CO_2 levels of the surface ocean also drive, on a geological timescale, the isotopic composition (vital effect) of Cenozoic coccoliths. These results have encouraged the use of coccolith vital effects as proxies for seawater CO_2 concentrations. However, a number of potential biases may hinder the application of the empirical calibrations from culture experiments to wild coccolith populations. This work formalises a transfer function linking the vital effects of fossil coccoliths to the constrained values of Pleistocene CO_{2aq}, with a view to developing a new tool for reconstructing older pCO_2 levels.

The calibration relies on the carbon and oxygen isotopic analyses of purified fractions of coccoliths from the North Atlantic core MD95-2037 across Termination II (~140–130 ka). Using the alkenone-based sea-surface temperature (SST) record available for the site, and atmospheric CO_2 concentrations from Antarctic ice cores, we derived values for the surface-ocean CO_2 concentrations across the deglaciation. We quantified the changing magnitude of the vital effect of the coccoliths to the presumed forcing by CO_2 and formulated a transfer function between the two parameters. We found a control of CO_2 concentrations on the isotopic difference ($\Delta^{18}O$, $\Delta^{13}C$) between coccoliths of different sizes produced across the penultimate glacial–interglacial transition. We discuss the factors complicating the obtained relationship, including the effect of growth-rate changes and/or air–sea disequilibrium. As a perspective of this work, we discuss the possible application of this calibration to more ancient periods in the Cenozoic, where direct measurements of pCO_2 are not available.

Experimental diagenesis and quantitative assessment of *Discoaster* overgrowth

Blandine Godet, Nicolas Pige
Université Lyon 1, ENSL, UJM, CNRS, LGL-TPE, F-69622 Villeurbanne, France; blandinegodet@hotmail.fr

Emanuela Mattioli
Université Lyon 1, ENSL, UJM, CNRS, LGL-TPE, F-69622 Villeurbanne, France & Institut Universitaire de France (IUF)

The increase in pressure and temperature during burial diagenesis leads to the dissolution and overgrowth of carbonate particles. Calcareous nannofossils represent a large part of the sediments deposited on the ocean floor, and their remains undergo significant changes during burial diagenesis that finally lead to a loss of the most delicate specimens. These partially or totally dissolve, ultimately modifying the assemblage composition. Along with dissolution, overgrowth occurs on the most resistant specimens, with subsequent changes in their morphologies.

This work aimed at quantifying the diagenesis-induced overgrowth in nannofossil assemblages, focusing on *Discoaster* specimens, which have previously been described as calcite receptors during experimental burial diagenesis (Adelseck et al., 1973). The diagenesis protocol described in that paper is updated here, and well-preserved assemblages from Paleogene and Eocene ODP samples (Leg 198, Site 1209) and a Pliocene sample from the Trubi Formation of Sicily were exposed to 27-day-long high-pressure (up to 1 kbar) and, separately, high-temperature (up to 300ºC) conditions, using artificial seawater as the medium. Overgrown discoasters were then measured through morphometry using a scanning electron microscope. This study allowed, for the first time, a quantitative assessment of the degree of overgrowth occurring in discoasters.

References

Adelseck, C.G., Geehan, G.W. & Roth, P.H. 1973. Experimental evidence for the selective dissolution and overgrowth of calcareous nannofossils during diagenesis. *Geological Society of America Bulletin*, **84**: 2755–2762. doi: 10.1130/0016-7606(1973)84<2755:eeftsd>2.0.co;2

Calcification of the *Gephyrocapsa* complex during the Mid-Brunhes Event

Alba González-Lanchas
Previously Department of Geology, University of Salamanca, Spain now Department of Earth Sciences, University of Oxford, Oxford, UK; alba.gonzalez-lanchas@earth.ox.ac.uk

José-Abel Flores
Department of Geology, University of Salamanca, Spain

Rosalind E. M. Rickaby
Department of Earth Sciences, University of Oxford, Oxford, UK

Andrés Rigual-Hernández
Department of Geology, University of Salamanca, Spain

El Mahdi Bendif, Odysseas A. Archontikis
Department of Earth Sciences, University of Oxford, Oxford, UK

Francisco J. Sierro, Montserrat Alonso-Garcia
Department of Geology, University of Salamanca, Spain

Coccolithophores of the Noelaerhabdaceae have contributed to modulating the global carbon cycle by increasing carbonate export and burial rates due to their recurrent enhanced production in low-eccentricity scenarios with an ~400-kyr cyclicity during the Pleistocene. Whether this variability also entailed a change in the degree of coccolithophore calcification is unknown, but plausible, since regulation of the carbon cycle at this scale would necessarily involve deep changes in the state of the ocean's carbonate chemistry.

We analysed the morphometries (size and mass) of the dominant *Gephyrocapsa* complex during the last minimum-eccentricity episode 400 kyr ago, encompassing the Mid-Brunhes Event (MBE), over a wide range of latitudinal environments across the North Atlantic Ocean region and the Mediterranean Sea. We captured an enhancement in *Gephyrocapsa* calcification coeval with high coccolithophore production led by mid-sized *Gephyrocapsa* specimens. An analysis of the diversity of the *Gephyrocapsa* complex allowed us to determine an increased calcification expressed by an array of morphotypes at the different sites. Such widespread enhanced calcification across the *Gephyrocapsa* complex supports the existence of a common trigger for a higher degree of calcification of a range of *Gephyrocapsa* during the MBE. This feature is plausibly related to changes in the seawater chemistry, such as an increase in HCO_3^-, that could explain the common response of *Gephyrocapsa* calcification observed at all sites.

This perspective critically underscores that the nature of the stimulus mediating orbital forcing and long-term phytoplankton evolution or adaptation could be embellished by changes in seawater carbonate chemistry as a critical component.

Reconstruction of surface-ocean dynamics during Termination V (MIS 12–MIS 11) on the Iberian margin (IODP Site U1386)

María González Martin, José-Abel Flores, Alba González-Lanchas, Montserrat Alonso García, Francisco Javier Sierro
Department of Geology, University of Salamanca, Salamanca, Spain; mariaglezmartin@usal.es

María Fernanda Sánchez-Goñi
Université de Bordeaux, UMR CNRS 5805 EPOC, Pessac, France & Ecole Pratique des Hautes Etudes (EPHE), PSL University, Pessac, France

Gabriel Hes
Université de Bordeaux, UMR CNRS 5805 EPOC, Pessac, France & Département de Géosciences, École Normale Supérieure, PSL Université, Paris, France

A high-resolution study of the glacial–interglacial transition MIS 12/MIS 11 (434–404 ka) was conducted by observing the productivity patterns of coccolithophore assemblages from Site U1386 of the Integrated Ocean Drilling Program (IODP) with the aim of reconstructing the oceanic surface dynamics of the Gulf of Cádiz. In addition, the pollen record from the same site provided information on the changes in wind and precipitation trajectories along the south-western Iberian margin during Termination V (MIS 12/MIS 11). The study of MIS 11 is important as it is considered to be a potential Holocene analogue.

The coccolithophore primary productivity was reconstructed using a primary productivity proxy (PPP = N values of small *Gephyrocapsa* + N values of *G. caribbeanica*). Temperature changes were studied by analysing cold-surface-water taxa of polar or subpolar origin (*Coccolithus pelagicus*) and warm-water taxa (WWT). To reconstruct the currents: 1) the percentage of reworked nannofossils from the Paleogene–Upper Cretaceous was analysed to understand the strength of the Mediterranean outflow water (MOW); and 2) the productivity of *G. muellerae* (Atlantic-water taxon) and small *Gephyrocapsa* were measured to determine the influence of the Portugal Current (PC) in the region. The pollen data provided insights into the climate of the continent and the strength of the westerlies in the period studied, and associated these with the variability of the North Atlantic Oscillation (NAO). The PPP and WWT group values were higher in the interglacial, while *C. pelagicus* (cold-water taxon) was more abundant in the glacial. This indicates that the productivity limitation was due to temperature, ruling out that the changes were caused by nearby upwelling. The reworked percentages confirmed that the MOW was most intense during MIS 12, associated with a dry and cold climate, and that it gradually decreased towards the interglacial. This may have triggered a resumption of Atlantic Meridional Overturning Circulation (AMOC), leading to one of the warmest high-latitude interglacials of the last 800 kyr (MIS 11). The PC was not very intense during MIS 12, but increased during the transition and stabilised at a medium intensity in MIS 11.

Overall, the data from our study provide new evidence for the important role of glacial–interglacial temperature changes on the primary productivity of coccolithophores in the Gulf of Cadiz during Termination V, affected by oceanic and atmospheric circulation patterns.

Aspidolithus parcus/*Broinsonia parca*: Some aspects of nannofossil morphometry around the Santonian/Campanian boundary

Paula Granero Ordóñez, Michael Wagreich
Department of Geology, University of Vienna, Althanstraße Josef-Holaubek-Platz14 2, 1090 Vienna, Austria; paula.granero.ordonez@univie.ac.at

In nannofossil biostratigraphy, the bioevent that defines the base of the Campanian is the first occurrence of large *Aspidolithus parcus parcus* (Stradner, 1963) Noël 1969 or *Broinsonia parca* subsp. *parca* (Stradner, 1963) Bukry, 1969 (of Nannotax3). The morphometry of the *Aspidolithus*/*Broinsonia* group is essential to identify the subspecies of the group. The generic attribution to *Aspidolithus* (without central-cross elements) or *Broinsonia* (with central-cross elements) is another problem in this taxon (see also Nannotax 3 and Miniati et al., 2020). So far, the evolutionary transition during the Late Cretaceous goes from small morphotypes with wide central-areas ('*Broinsonia*' *enormis* [Shumenko, 1968] Manivit, 1971) to large morphotypes (>10 μm) with decreasing central-area widths and increasing rim/shield widths (*Aspidolithus parcus* group).

We used, herein, two sections (Postalm/NCA, Loibichl/RFZ) from the Eastern Alps of Austria to document the morphometry around the Santonian/Campanian boundary interval using 100x magnification and an oil-immersion light microscope for the morphometric measurements. The critical subspecies parameters were the maximum length (long diameter) of the coccolith, the ratio of the width of the outer rim/shield (b) to the small diameter of the central-area (a) (e.g. Gardin et al., 2001). The number and arrangement of perforations in the central-area provided another characteristic feature (e.g. Lauer, 1975). At Postalm (Wolfgring et al., 2018; moderate preservation with overgrowth), the bioevent was marked by the rare first occurrence (FO) of large *A. parcus parcus* with long diameters of between 9.5 and 12.5 μm and the b/a < 2. Five transitional morphotypes could be distinguished: 1) *B. enormis* subsp. 1, with a length of <9 μm (usually 6–8 μm) and a b/a ≥ 2; 2) *B. enormis* subsp. 2, with a length of <9 μm (usually 6–8 μm) and a b/a < 2 (usually down to 1.3). Some authors have already included this subspecies into *A. parcus parcus* 'small morphotype' (e.g. Miniati et al., 2020; 3) *A. parcus expansus* (Wise & Watkins *in* Wise, 1983) Perch-Nielsen, 1984, with a length of >9 μm (usually >10 μm) and a b/a ≥ 2 (usually 3–4); 4) *A. parcus parcus*, with a length of >9 μm (usually >10 μm) and a b/a < 2 to ≥1. Only this form is considered to be the bioevent characterising the Santonian/Campanian boundary and the base for standard zones UC14a (Burnett et al., 1998) and CC18a (Sissingh, 1977); and 5) *A. parcus constrictus* (Hattner et al., 1980) Perch-Nielsen, 1984, with a length of >9 μm (usually 9.5–13 μm) and a b/a < 1, which defines the base of the standard subzones UC14b and CC18b.

Adding data from the better-preserved Loibichl section, where the perforations in the central-area could easily be observed due to very minor overgrowth, indicated the following: 1) *B. enormis* and the 'small morphotypes' of the *A. parcus* group display rather different numbers of perforations between the two localities, with 12–20 (ROM) and 4–8 (LOI). However, due to their small size, data bias was significant. *A. parcus expansus* showed a variation of >20 to 8; 2) the evolution of large *A. parcus parcus* saw a reduction in the number of perforations to around 5–8 (2 per central-area sector); and 3) the FO of *A. parcus constrictus* was marked by a further reduction to about 4–6 (1–2 per central-area sector), with an even smaller number in younger intervals.

References

Burnett, J.A., with contributions from Gallagher, L.T. & Hampton, M.J. 1998. Upper Cretaceous. *In*: P.R. Bown (Ed.). *Calcareous nannofossil biostratigraphy*. British Micropalaeontological Society Publications Series, Chapman and Hall, London: 132–199.

Gardin, S., Del Panta, F., Monechi, S. & Pozzi, M. 2001. Chapter E4. A Tethyan reference record for the Campanian and Maastrichtian stages: The Bottaccione section (central Italy)—Review of data and new calcareous nannofossil results. *Developments in Palaeontology and Stratigraphy*, **19**: 745–757.

Lauer, G. 1975. Evolutionary trends in the Arkhangelskiellaceae (calcareous nannoplankton) of the Upper Cretaceous of central Oman, SE Arabia. *Archives des Sciences de Genève*, **28**: 259–262.

Miniati, F., Petrizzo, M.R., Falzoni, F. & Erba, E. 2020. Calcareous plankton biostratigraphy of the Santonian–Campanian boundary interval in the Bottaccione section (Umbria–Marche Basin, central Italy). *Rivista Italiana di Paleontologia e Stratigrafia*, **126**: 783–801.

Sissingh, W. 1977. Biostratigraphy of Cretaceous calcareous nannoplankton. *Geologie en Mijnbouw*, **56**: 37–56.

Wolfgring, E., Wagreich, M., Dinarès-Turell, J., Gier, S., Böhm, K., Sames, B., Spötl, C. & Popp, F. 2018. The Santonian–Campanian boundary and the end of the Long Cretaceous Normal Polarity Chron: Isotope and plankton stratigraphy of a pelagic reference section in the NW Tethys (Austria). *Newsletters on Stratigraphy*, **51**.

Young, J.R., Bown, P.R. & Lees, J.A. 2017. Nannotax3 website. International Nannoplankton Association. Accessed 2 May 2021. URL: https://www.mikrotax.org/Nannotax3.

Coccolithophore ballasting effect on marine microplastics export and accumulation

Michaël Grelaud, Laura Simon-Sánchez, Patrizia Ziveri

Institut de Ciència i Tecnologia Ambientals, Universitat Autònoma de Barcelona, Bellaterra, Spain; michael.grelaud@uab.cat

Since the early 1950s, annual global plastics production has increased exponentially, reaching 367 million t in 2020. Through waste mismanagement, and illegal dumping, shipping or fishery activities, for example, a large portion (~8–10 million t) ends up in the marine system every year (Boucher et al., 2017). Once in the environment, the plastic waste undergoes fragmentation through various processes, leading to the formation of the notorious microplastics (1–5000 μm) and nanoplastics (<1 μm). However, this floating contamination, which is concentrated in the five subtropical gyres (i.e. garbage patches), represents only 1% of the total budget (Koelmans et al., 2017), pointing to seafloor sediments as the ultimate destination for this pollution.

It was hypothesised that, in the ocean, the floating microplastics can form aggregates embedded in marine snow and faecal pellets. The coupling of this biotic and abiotic removal is suspected to be the main pathway for microplastics to reach the seafloor, although the mechanisms behind this removal remain poorly understood. In order to test this hypothesis, we measured the accumulation of coccolithophores over the last ~60 yr in a well-preserved and dated sediment core retrieved from the prodelta of the Ebro River (north-western Mediterranean Sea). These data were compared to the accumulation of small microplastics (10–1000 μm) measured in the same core (Simon-Sánchez et al., in review).

The results show that the microplastics mass accumulating in these sediments mimics the exponential increase in global plastics production over the last 70 yr, making comparison with the coccolithophore record irrelevant, unless the exponential trend is removed from the microplastics record. In this case, the detrended microplastics record parallels the absolute abundances of coccolithophores since the mid-1960s, showing, for the first time, the direct relationship between the surface export production and the removal of microplastics from the surface to the seafloor.

References

Boucher, J. & Friot, D. 2017. *Primary microplastics in the oceans: A global evaluation of sources*. Gland, Switzerland: IUCN, 43 pp.

Koelmans, A.A., Kooi, M., Law, K.L. & van Sebille, E. 2017. All is not lost: Deriving a top-down mass budget of plastic at sea. *Environmental Research Letters*, **12**(11): 1–9.

Simon-Sánchez, L., Grelaud, M., Lorenz, C., Garcia-Orellana, J., Vianello, A., Liu, F., Vollersten, J. & Ziveri, P. In review. Sediment cores revealing the plastic age? Microplastic preservation in coastal sedimentary records.

Evolution and adaptation of coccolithophores to recent environmental changes in the Mediterranean Sea

Majd Habib
CEREGE, Aix-Marseille Université, CNRS, BP80 Cedex4, 13545 Aix-en-Provence, France & National Council for Scientific Research in Lebanon, National Center for Marine Sciences, Batroun, Lebanon; habib@cerege.fr

Abed El Rahman Hassoun
National Council for Scientific Research in Lebanon, National Center for Marine Sciences, Batroun, Lebanon

Luc Beaufort
CEREGE, Aix-Marseille Université, CNRS, BP80 Cedex4, 13545 Aix-en-Provence, France

The semi-enclosed Mediterranean Sea is a hotspot for climate change, where faster warming, deoxygenation and acidification rates are a regular occurrence that have affected its unique marine ecosystems and, in particular, the calcifying organisms, such as corals, foraminifera and coccolithophores. The latter are phytoplanktonic species that are major carbonate producers in the modern oceans, and thus they play a major role in the oceanic carbon cycle.

The quantification of coccolithophore assemblages and the assessment of their relationships with environmental drivers is lacking in Lebanon. To address this, this work focused on studying the coccolithophore species in the upper 150 m of the eastern Mediterranean Sea off Batroun and Beirut. For comparison, samples from the western Mediterranean Sea off Marseille were also studied. Seawater parameters (temperature, salinity, pH, alkalinity and total dissolved inorganic carbon) were measured to derive the carbonate chemistry of the collected water. Our preliminary results show that, while *Emiliania huxleyi* is the dominant species, several other species, such as *Syracosphaera pulchra*, *Rhabdosphaera clavigera* and *Florisphaera profunda* were also found in abundance. Morphometric parameters, such as area, mass and thickness of the coccoliths and coccospheres, were measured with the help of artificial intelligence and automated morphometric software. Our results highlight the importance of several parameters in unraveling the distribution of *E. huxleyi*. We found that the combined effects of several physical and chemical oceanic parameters control the morphometry and abundance of coccolithophores in the Mediterranean Sea.

Marine phytoplankton biogeography before the recent global ocean warming

Kyoko Hagino, Yurika Ujiie, Masao Iwai
Center for Advanced Marine Core Research, Kochi University, Monobe B-200, Nankoku, Japan; hagino@kochi-u.ac.jp

Tatsuhiko Hoshino
Kochi Institute for Core Sample Research, JAMSTEC, Monobe B-200, Nankoku, Japan

Richard Jordan
Faculty of Science, Yamagata University, 1-4-12 Kojirakawa-machi, Yamagata 990-8560, Japan

Masayuki Utsunomiya, Yuichiro Tanaka
Geological Survey of Japan, AIST, 1-1-1, Higashi, Tsukuba 305-8567, Japan

Jeremy R. Young
University College London, Gower Place, London WC1E 6BT, UK

El Mahdi Bendif
Department of Earth Science, University of Oxford, South Parks Road, Oxford OX1 3AN, UK

Ian Probert
Station Biologique de Roscoff, Place Georges Teissier, 29680 Roscoff, France

Global ocean warming has accelerated since the 1990s, resulting in the modification of marine phytoplankton habitats. However, the evidence of such an environmental impact on the marine phytoplankton is limited. During the 1960s and 1970s, a huge collection of filter samples was obtained from across the world ocean by Profs Andrew McIntyre of the Lamont–Doherty Earth Observatory and Hisatake Okada of Hokkaido University. Their filter collection provided us with a unique opportunity to reconstruct the photic biosphere before the acceleration of ocean warming. Okada & McIntyre obtained over 5000 filtered seawater samples, from which they revealed floral zones and seasonal changes in the coccolithophores of the Atlantic and Pacific Oceans based on electron microscope studies of ~1500 filter samples (e.g. McIntyre & Bé, 1967; Okada & Honjo, 1973; Okada & McIntyre, 1979). In this study, we assess the diversity of coccolithophores and parmales through morphological and eDNA metabarcoding studies. Our comprehensive survey, employing morphological–molecular approaches will provide important information on the phytoplankton community structure in the 1960s–1970s, and will enable us to make a comparison with those found in the modern ocean. In this talk, we will introduce our ongoing project, report on its current progress, and show some of our preliminary results based on microscope observations and metabarcoding analyses.

References

Okada, H. & Honjo, S. 1973. The distribution of oceanic coccolithophorids in the Pacific. *Deep-Sea Research*, **20**: 355–374.

Okada, H. & McIntyre, A. 1979. Seasonal distribution of modern coccolithophores in the western North Atlantic Ocean. *Marine Biology*, **54**: 319–328.

McIntyre, A. & Bé, A.W.H. 1967. Modern coccolithophoridae of the Atlantic Ocean – I. Placoliths and Cyrtoliths. *Deep-Sea Research and Oceanographic Abstracts*, **14**: 565–597.

Novel approaches to high-resolution coccolith geochemistry through the Late Pliocene *Discoaster* extinctions

Emma M. Hanson, Tom Dunkley Jones
School of Geography, Earth & Environmental Sciences, University of Birmingham, Birmingham, UK; Exh601@student.bham.ac.uk

The climatic transition from the warmer Pliocene to the high-amplitude glacial–interglacial cyclicity of the Pleistocene was clearly associated with a series of species extinctions in the discoasters. Although these had previously been a major component of tropical to subtropical calcareous nannofossil assemblages, they suffered throughout the Late Pliocene, culminating in a series of five species extinctions over a period of ~1 Myr, with the final occurrence of *Discoaster brouweri* occurring at 1.9 Ma. The immediate proximal causes of the extinction are currently unknown, although throughout this period, there was a clear trend in declining total coccolithophore species diversity and size, and an overall transition into a more intensely glaciated climate state.

To investigate these events, a novel size separation technique was employed to generate high-resolution coccolith-sized specific isotopic and Sr/Ca records throughout the Pliocene–Pleistocene transition from IODP Site U1482 (Exp. 363) on the north-western Australian continental margin. By utilising this novel technique, we were able to increase the speed of sample processing to rapidly generate geochemical records from the large (~7–10 μm) versus small (<4 μm) coccolith size fractions. In the isotope records, there was a consistent offset of ~1‰ in the carbon isotopes. These results are consistent with previous low-resolution, but long-term, size-fraction isotopic records, and demonstrate that these carbon isotopic offsets are retained through orbital-scale variations in the climate system.

Coccolithophore export production in the deep Ionian Sea, eastern Mediterranean (NESTOR site sediment trap, 4300 m deep)

Sikandar Hayat
National and Kapodistrian University of Athens, Faculty of Geology & Geoenvironment, Panepistimioupolis, 15784 Athens, Greece & Department of Earth Sciences, University of Lille 1, Cité Scientifique, 59655 Villeneuve d'Ascq, France; sikandar.hayat.etu@univ-lille.fr

Elisavet Skampa
National and Kapodistrian University of Athens, Faculty of Geology & Geoenvironment, Panepistimioupolis, 15784 Athens, Greece

Alexandra Gogou, Spyros Stavrakakis, Constantine Parinos
Hellenic Centre for Marine Research, Institute of Oceanography, PO Box 712, 19013 Anavyssos, Greece

Maria Triantaphyllou
National and Kapodistrian University of Athens, Faculty of Geology &Geoenvironment, Panepistimioupolis, 15784 Athens, Greece

This study was the first attempt to understand the coccolith flux and its seasonal variability in one of the deepest parts of the Mediterranean located in the south-eastern Ionian Sea. The study area has a complicated geomorphology, comprising valleys, steep slopes and deep basins (Stavrakakis et al., 2013). Sediments for microscopic analysis were obtained from the deepest time-series sediment trap (4300 m), moored at the NESTOR site from February 2015 to December 2017. The quantitative analysis was carried out using 1000x magnification with a polarised light microscope. A total of 21 species of heterococcoliths were identified. The maximum coccolith flux was observed for March 2015 (1.10×10^9 coccoliths m^{-2} day^{-1}) and the minimum value was recorded for June 2015 (1.25×10^8 coccoliths m^{-2} day^{-1}). The dominant species in all the samples was *Emiliania huxleyi*, constituting 50–70% of the total coccolith count, while the second most abundant species was *Florisphaera profunda*, constituting 8–25% of the total coccolith count. *Emiliania huxleyi* and *F. profunda*, together with *Umbilicosphaera sibogae* (up to 8%), *Rhabdosphaera clavigera* (up to 4.8%), *Syracosphaera pulchra* (up to 5.6%), *Calciosolenia brasiliensis* (up to 3.2%), *Gladiolithus flabellatus* (up to 3.9%) and holococcoliths (up to 3%) accounted for 95–97% of the total coccolith assemblages. The highest abundance of *E. huxleyi* was recorded in March 2015 (8.4×10^8 coccoliths m^{-2} day^{-1}). The highest abundance of *F. profunda* was recorded in October 2015, contributing 1.40×10^8 coccoliths m^{-2} day^{-1} in the first half of the month and 1.37×10^8 coccoliths m^{-2} day^{-1} during the second half. The occurrence of complete coccospheres was rare, mostly due to the processing of the samples for coccolith analysis. Only a few coccospheres of *S. pulchra, E. huxleyi, U. sibogae, R. clavigera* and *Algirosphaera robusta* were observed. The average coccolith flux for the NESTOR site at a relatively shallow depth (2000 m), as reported by Skampa et al. (2020), was lower than that observed in the present study, and a time lag of 45 days was observed for the summer maximum flux between the two traps. This time lag between the shallow and deep-water coccolithophore maxima has also been reported from other studies in the eastern Mediterranean, such as the Cretan Sea (Triantaphyllou et al., 2004). The higher coccolith flux at 4300 m compared to the shallower depth can be attributed to lateral advection, resuspension and/or the influence of eastern Mediterranean deep waters (EMDWs) (Stavrakakis et al., 2013). The summer maxima observed by Skampa et al. (2020) at 2000 m appeared in early autumn at 4300 m (present study). A plausible explanation for this unusual summer peak could be linked to physical processes that enhance the availability of nutrients in the surface waters, such as upwelling processes due to seasonal anticyclonic-gyre variability and atmospheric input. Acknowledgement: Erasmus Mundus Joint Master's Degree Program PANGEA.

References

Skampa, E., Triantaphyllou, M.V., Dimiza, M.D., Gogou, A., Malinverno, E., Stavrakakis, S., Parinos, C., Panagiotopoulos, I.P., Tselenti, D., Archontikis, O. & Baumann, K.H. 2020. Coccolithophore export in three deep-sea sites of the Aegean and Ionian Seas (eastern Mediterranean): Biogeographical patterns and biogenic carbonate fluxes. *Deep Sea Research Part II: Topical Studies in Oceanography*, **171**: 104690.

Stavrakakis, S., Gogou, A., Krasakopoulou, E., Karageorgis, A.P., Kontoyiannis, H., Rousakis, G., Velaoras, D., Perivoliotis, L., Kambouri, G., Stavrakaki, I. & Lykousis, V. 2013. Downward fluxes of sinking particulate matter in the deep Ionian Sea (NESTOR site), eastern Mediterranean: Seasonal and interannual variability. *Biogeosciences*, **10**: 7235–7254.

Triantaphyllou, M.V., Ziveri, P. & Tselepides, A. 2004. Coccolithophore export production and response to seasonal surface-water variability in the oligotrophic Cretan Sea (NE Mediterranean). *Micropaleontology*, **50**: 127–144.

Rates of phenotypic evolution in coccolithophores

Jorijntje Henderiks
Department of Earth Sciences, Uppsala University, SE-752 36 Uppsala, Sweden; jorijntje.henderiks@geo.uu.se
Kjetil L. Voje
Natural History Museum, University of Oslo, NO-0562 Oslo, Norway

By studying coccolithophores and their fossil coccoliths, we may gain detailed knowledge about the actual workings of phenotypic evolution. However, despite many efforts to describe the tempo and modes of evolution from the fossil record, it remains difficult to identify the processes responsible for the patterns observed. Fossil coccolith time-series offer some of the most detailed and well-sampled records of evolutionary change, spanning millions of years, which can also be readily compared to proxy records of past climates to address a range of process-oriented questions. Much work has been done to document the patterns of past diversification and phenotypic change in coccolithophores, and several working hypotheses have been formulated that address distinct macroevolutionary coccolith size changes in terms of speciation and climatic adaptation. Yet, concerted efforts to understand what actual processes and rates of evolution underpin the observed patterns have only just begun and, to date, studies have mainly focused on one single coccolithophore family—that of the ubiquitous species, *Emiliania huxleyi*, and its closest relatives in the Noelaerhabdaceae family. Here, we present an analysis of the rates of phenotypic evolution in several coccolithophore lineages, and explore why these vary across time-scales. We use a range of statistical models to describe and discuss 'bursts of evolution', as well as the more stationary trait dynamics during 'evolutionary stasis'.

An experimental study on post-mortem dissolution and overgrowth processes affecting coccolith assemblages: A rapid and complex process

Katarína Holcová
Institute of Geology and Palaeontology, Charles University, Albertov 6, 128 43 Praha 2, Czech Republic; holcova@natur.cuni.cz
Filip Scheiner
Institute of Geology and Palaeontology, Charles University, Albertov 6, 128 43 Praha 2, Czech Republic & Institute of Geology of the Czech Academy of Sciences, Rozvojová 269, 165 00 Praha 6 Lysolaje, Czech Republic

This study summarised the effects of short-lasting pH oscillations on post-mortem coccolith morphological features and the abundances and compositions of calcareous nannoplankton assemblages in three distinct types of material: 1) Cretaceous chalk; 2) Miocene marls; and 3) Late Holocene calcareous ooze. Two independent experimental runs in a semi-enclosed system setting were realised in order to observe changes in the assemblages. One experiment was realised with no barrier to the survival of bacteria and, by contrast, the second inhibited their potential effect on the studied system. The pH was gradually decreased in the range of 8.3–6.4 using a simplified reaction of CO_2 with H_2O to form a weak carbonic acid (H_2CO_3), thereby affecting CO_3^{2-} and Ca^{2+} mobilisation. In addition, a subsequent overgrowth study was carried out during spontaneous degassing accompanied by a gradual rise in pH. The experiment revealed that the processes and intensity of coccolith corrosion and subsequent overgrowth build-ups were influenced by a plethora of different factors, such as: 1) the pH and the associated seawater chemistry; 2) the mineral composition of the sediment; 3) the presence of coccoliths within a protective substrate (fecal pellets, pores, pits); and 4) the presence/absence of bacteria. Nannoplankton assemblages with etched or overgrown coccoliths showed that the observed relative abundances of the taxa experienced alteration from the original compositions. Additionally, extreme pH oscillations may result in enhanced morphological changes that make coccoliths unidentifiable structures, and might even result in the absence of coccoliths in the fossil record.

A comparison with actual fossil assemblages showed that all morphological types observed during this laboratory experiment were also present in the fossil record. Our results suggest that the intensity of coccolith overgrowth can be linked with marine productivity in cases where the samples were deposited clearly above the lysocline and there was no major input of terrigenous organic matter. We assume that the abundances of dissolution-resistant species and of nannoplankton in the fossil record depend on a combination of primary abundance values and shifts induced by post-mortem dissolution.

Strontium isotope stratigraphy vs calcareous nannoplankton datums in an epicontinental sea: A case study from the Miocene Paratethys

Katarína Holcová
Institute of Geology and Palaeontology, Charles University, Albertov 6, 128 43 Praha 2, Czech Republic; holcova@natur.cuni.cz

Filip Scheiner
Institute of Geology and Palaeontology, Charles University, Albertov 6, 128 43 Praha 2, Czech Republic & Institute of Geology of the Czech Academy of Sciences, Rozvojová 269, 165 00 Praha 6 Lysolaje, Czech Republic

Lukáš Ackerman, Jan Rejšek
Institute of Geology of the Czech Academy of Sciences, Rozvojová 269, 165 00 Praha 6 Lysolaje, Czech Republic

Václav Santolík
Institute of Geology and Palaeontology, Charles University, Albertov 6, 128 43 Praha 2, Czech Republic & Institute of Geology of the Czech Academy of Sciences, Rozvojová 269, 165 00 Praha 6 Lysolaje, Czech Republic

Biostratigraphic correlations in semi-enclosed epicontinental seas are affected by the many specific palaeoenvironmental patterns that occurred in these marine basins, which do not have precise Recent equivalents. Therefore, the following problems arise concerning the use of biostratigraphy and also strontium isotope stratigraphy (SIS): 1) the timing of bioevents was dependent on specific palaeoenvironmental conditions that were limiting factors for the survival of the index organisms in particular basins. This is especially true for basins that were located along communication gateways; and 2) the specificity of seawater chemistry arising from varying fresh-water inputs, together with the rock weathering intensity in the surrounding drainage areas (the weathering of carbonates can significantly influence the $^{87}Sr/^{86}Sr$ ratio).

The aim of our study was to compare a large $^{87}Sr/^{86}Sr$ ratio dataset (100 values obtained from benthic and planktonic foraminifera, otoliths and molluscs) with calcareous nannoplankton datums for the Upper Burdigalian–Serravallian interval. As our study area, we selected the Eocene to Miocene system of European epicontinental seas called the Paratethys, which was connected periodically with the surrounding oceanic domains. The following bioevents can be identified in this interval in the selected study area: the last occurrence (LO) of *Helicosphaera ampliaperta*, the first occurrence (FO) and LO of *H. waltrans*, the FO of *H. walbersdorfensis* and, finally, the LO of *Sphenolithus heteromorphus*. To conclude, the $^{87}Sr/^{86}Sr$ ratio was significantly influenced by the characteristics of the weathered rocks of the surrounding drainage areas in the studied epicontinental basins. Carbonate rocks can significantly shift the $^{87}Sr/^{86}Sr$ ratio, while in areas with predominantly clastic rocks, $^{87}Sr/^{86}Sr$ ratios become closer to their oceanic values.

Ultrastructure and taxonomy of the family Fasciculithaceae

Richard Howe
Ellington Geological Services, 1414 Lumpkin Road, Houston, TX 77043, USA; richard.howe@ellingtongeo.com

The family Fasciculithaceae are a group of Paleogene coccolith species with cylindrical, conical or discoidal coccoliths comprising several vertically stacked cycles of elements radiating from a central point. I will describe the ultrastructure and high-level taxonomy in detail. In plan view, the cycles are strictly circular, and vary in height and width. The lowest cycle is the column, the base of which is interpreted to be the proximal surface of the coccolith. Above the column, a cycle of variable height and width is termed the 'lateral cycle'. Above the lateral element cycle, is the highest cycle, termed the 'cone cycle'. The upper surface of the cone cycle is interpreted to be the distal surface of the coccolith. Genera and species are differentiated by varying proportions and shapes of the three cycles. This basic ultrastructure is shared among species and genera in the Fasciculithaceae. The genera included here are *Gomphiolithus*, *Lithoptychius*, *Fasciculithus*, *Bomolithus*, *Tectulithus* and *Heliotrochus*.

The genus *Heliolithus* has often been included in the Fasciculithaceae. Two vertically stacked circular cycles are present, which flare outwards. Neither of these cycles is interpreted here as being a column. *Heliolithus* is probably derived from *Bomolithus* or *Tectulithus* through loss of the column, which would make the two cycles homologous to the lateral and cone cycles of fasciculithids. It is difficult to assign either of the two cycles in *Heliolithus* to either the lateral or cone cycles of fasciculithids with any certainty. Because of this uncertainty in the exact relationship between *Heliolithus* and the fasciculithids, species of *Heliolithus* are assigned to the family Heliolithaceae.

Upper Cretaceous calcareous nannofossils from Gamba, southern Tibet and their palaeoceanographic implications

Shijun Jiang, Yasu Wang

College of Oceanography, Hohai University, Nanjing 210098, China & Southern Marine Science and Engineering Guangdong Laboratory, Zhuhai 519082, China; sjiang@hhu.edu.cn

Hong Su
College of Life Science and Technology, Jinan University, Guangzhou 510632, China

Richard W. Jordan
Faculty of Science, Yamagata University, Yamagata 990-8560, Japan

Calcareous nannofossils have proven to be a powerful tool in the division and correlation of Mesozoic and Cenozoic marine strata due to their high abundance and robust morphology. Marine Jurassic, Cretaceous and Paleogene outcrops are well exposed in southern Tibet. This part of the eastern Tethyan realm is characterised by high altitudes (usually 4000 m above sea level) and bare ground with very sparse to no vegetation for the entire year. The Chaqiela section in the Gamba area is one of the classic sections for studying Mesozoic biostratigraphy and palaeoceanography, comprising the Chaqiela, Lengqingre, Gangbacunkou, Jiubao and Zongshan Formations. It is noteworthy that, possibly due to limited communication in the mid-20th century, when a massive survey was launched, there is a notable difference in the definitions of the Chaqiela and Gangbacunkou Formations (including the Lengqingre, Xiawu Chubo and Jiubao Formations) among different scholars. Even for the same authors, the positions of the formation boundaries are not fixed. Here, we present calcareous nannofossils from the black calcareous shales of the Lengqingre Formation, which was previously dated as late Albian–Turonian.

Well-preserved and abundant calcareous nannofossil assemblages were observed and counted. The common taxa include *Biscutum constans*, *Discorhabdus ignotus*, *Eiffellithus turriseiffelii*, *Eprolithus floralis*, *Prediscosphaera cretacea*, *Rhagodiscus achlyostaurion*, *Tranolithus orionatus*, *Watznaueria barnesiae* and *Zeugrhabdotus erectus*. The UC biozonation was applied based on the stratigraphical distribution of zonal markers in the section, such as *Corollithion kennedyi* (base at 100.45 Ma, top at 94.64 Ma), *Gartnerago segmentatum* (base at 98.26 Ma) and *Rhagodiscus asper* (base at 94.30 Ma). The studied section spans UC0–UC3 (or NC10a–NC10b) and is thus actually Early Cenomanian in age (Late Cretaceous).

From the bottom to the top of the section, the calcareous nannoflora evolved from assemblages dominated by *Zeugrhabdotus erectus* (Ze)–*Discorhabdus ignotus* (Di)–*Biscutum constans* (Bc)–*Watznaueria barnesiae* (Wb) to Bc–Di–Wb–Ze and Wb–Ze assemblages. *Zeugrhabdotus erectus*, *D. ignotus* and *B. constans* are typically described as high-productivity/fertility indicators, while *W. barnesiae* is a typically oligotrophic species. The evolution of the calcareous nannoplankton, quantified using nutrient and temperature indices (Herrle et al., 2003; Watkins, 2005), reflects an up-section decrease in primary productivity and an up-section warming during the Early Cenomanian, which is consistent with the western Tethys region, as reported by Bottini and Erba (2018), which can be attributed to nutrient reduction due to warming-related water-column stratification. Most notably, the accompanying warming and eutrophication in the lower part of the section correspond to the top of UC0 (or NC10a), suggesting the possible existence of Ocean Anoxic Event 1d (OAE 1d), which, to date, has not been reported from this region. Acknowledgements: This work was jointly funded by the National Natural Science Foundation of China (No. 41888101, 41672004) and the Southern Ocean Science and Engineering Guangdong Laboratory (Zhuhai) Innovation Team Construction Project (No. 311021002).

Coccolithophore abundance and degree of calcification and their contribution to particulate inorganic carbon in the South China Sea

Xiaobo Jin, Chuanlian Liu, Juan Xu
State Key Laboratory of Marine Geology, Tongji University, Shanghai, China; evidently@163.com
Weifang Chen, Xianghui Guo
State Key Laboratory of Marine Environmental Science, Xiamen University, Xiamen, China

Particulate inorganic carbon (PIC) production and export to the deep ocean are important processes in water-column carbonate cycling. Biochemical investigations have shown that modern seawater PIC in high-latitude eutrophic waters is contributed by the marine calcifying algae—coccolithophores—which are constituted almost entirely of individuals of the species *Emiliania huxleyi*. This allows a predictability of the seawater PIC in these high-fertility regions based on satellite remote sensing. However, the PIC in low-productivity surface waters, which accounts for 70% of the area of the global ocean, the subsurface PIC maximum may not be well constrained by satellite.

Here, using samples from a biochemistry cruise in the South China Sea, we investigated seawater coccolithophore cell and coccolith abundances, the degree of *E. huxleyi* coccolith calcification, and PIC concentrations in the deep chlorophyll-maximum layers, aiming to improve our understanding of PIC production in this low-productivity region. Our results demonstrate the control of water-column nutrient levels on the geographical (horizontal) distribution of Noelaerhabdaceae coccolithophores (*E. huxleyi* and *Gephyrocapsa oceanica*) in the investigated area, and also indicate an insensitive response of degree of calcification in *E. huxleyi* coccoliths to carbonate chemistry. Although Noelaerhabdaceae coccoliths are the major components of deep-sea-sediment carbonate, on average, they contributed <18% of the suspended PIC in the investigated seawater samples, indicating multiple sources for the highly variable suspended PIC in the subsurface oligotrophic water. The production of Noelaerhabdaceae coccoliths greatly depends on local environmental conditions, and this highlights the importance of field investigations in low-fertility areas in order to evaluate global PIC productivity.

Extant coccolithophore distribution in the Mediterranean Sea: A review

Roberta Johnson, Gerald Langer, Michael Grelaud
Institut de Ciència i Tecnologia Ambientals, Universitat Autònoma de Barcelona, Barcelona, Spain; roberta.johnson@uab.cat
Patrizia Ziveri
Institut de Ciència i Tecnologia Ambientals, Universitat Autònoma de Barcelona, Barcelona, Spain & Institució Catalana de Recerca i Estudis Avancats (ICREA), Barcelona, Spain

We present a systematic review of extant coccolithophore studies in the Mediterranean Sea. We compare coccolithophore communities and their ecological preferences and show the influence of environmental factors on their abundance. We consider differences between specific biogeochemical regions in the Mediterranean Sea including the Adriatic, Aegean, Cretan, Ionian, Ligurian, Balearic, Tyrrhenian and Alboran Seas, the Levantine Basin, as well as the Strait of Sicily and the Gulf of Sidra. There will be a particular focus on the differences between the two major sub-basins—eastern and western—of the Mediterranean Sea. A total of 59 studies were selected, starting from 1990, 32 of which focus solely on coccolithophores, while 27 examine the entire phytoplankton community.

The western Mediterranean Sea is underrepresented in coccolithophore research, with approximately 25% of all studies conducted in this sub-basin (14 studies compared to 39 in the eastern basin). The Aegean and Adriatic Seas are the most studied regions, followed by the Ionian and Tyrrhenian Seas (the most studied region in the western Mediterranean). Summer is the most represented season (24 studies), followed by spring (20 studies), autumn (10) and winter (eight studies). In the eastern Mediterranean, coccolithophores make up an average of 11% of the phytoplankton community, whereas in the western basin, they make up 15.6% of the phytoplankton community (Alboran Sea). The mean average abundance is greater in the eastern than in the western Mediterranean (2×10^4 L^{-1} $\pm$ 2.3×10^4 L^{-1} compared with 1.8×10^4 L^{-1} $\pm$ 1.6×10^4 L^{-1}, respectively). The average maximum abundance is also greater in the eastern Mediterranean Sea compared to the western (20.7×10^4 L^{-1} compared to 15.4×10^4 L^{-1}).

The most common species across the Mediterranean Sea is *Emiliania huxleyi*, with other common genera including *Rhabdosphaera* and *Syracosphaera*. There are many differences when reporting findings (cells per L^{-1}, percent relative abundance, percent frequency of occurrence, flux), and many studies do not include raw data, making direct comparisons difficult. Studies that focus on the entire phytoplankton community may be underestimating coccolithophore abundance and species diversity through the use of inappropriate counting methodology. Of the 14 studies in the western Mediterranean, only six used inverted light microscopy, suggesting that abundance estimates for this region could be underestimated. Further field studies in this sub-basin using suitable methodologies could improve abundance and species diversity estimates.

Middle Miocene to Pleistocene nannofossil biostratigraphy of the North Atlantic: Preliminary results from IODP Expedition 395C, Reykjanes Ridge

Boris-Theofanis Karatsolis
Department of Earth Sciences, Uppsala University, Villavägen 16, 754 30 Uppsala, Sweden; boris.karatsolis@geo.uu.se
Anita Di Chiara
Istituto Nazionale di Geofisica e Vulcanologia (INGV), Via di Vigna Murata 605, 00143 Rome, Italy
Sara Satolli
Department of Engineering and Geology, University of Chieti-Pescara, Via dei Vestini 31, 66100 Chieti Scalo, Italy
Sarah Friedman
Department of Geology and Geography, Georgia Southern University, 68 Georgia Avenue, Statesboro, GA 30458, USA
Expedition 395C/395 scientific participants
https://iodp.tamu.edu/scienceops/precruise/reykjanes/participants.html

During the summer of 2021 (June–August), IODP Expedition 395C operated south-west of Iceland and drilled a transect eastwards of the modern Mid-Atlantic Ridge (between 20 and 30ºW) at a latitude of ~60ºN. Sedimentary sections reaching the basaltic basement were successfully recovered from four sites—Holes U1555H, U1563A, U1554E and U1562A. The age of the acoustic basement, estimated from magnetic anomalies, varied from 14.2 Ma for the site located furthest from the ridge (U1562) and 2.8 Ma for the site most proximal to the ridge (U1555). Here, we present a preliminary Middle Miocene to Pleistocene nannofossil biostratigraphy for the recovered sediments. Nannofossils were abundant in most samples, with moderate to good preservation that generally improved towards the Late Pliocene to Pleistocene. In total, 28 bioevents were identified and assigned an age based on the Neogene time-scale of Raffi et al. (2020). Several biohorizons could be identified across the sites, including the top occurrence of *Reticulofenestra pseudoumbilicus* at 3.82 Ma (base of Zone NN16 of Martini, 1971), the top occurrence of *Helicosphaera sellii* at 1.24 Ma, the top occurrence of *Pseudoemiliania lacunosa* at 0.43 Ma (base of Zone NN20) and the base occurrence of *Emiliania huxleyi* at 0.29 Ma (base of Zone NN21). The top occurrence of *Discoaster brouweri* at 1.93 Ma was only observed in Hole U1555H, due to this species' low abundance and intermittent presence. Most of the identified bioevents demonstrated very good correlation with the preliminary Late Pliocene to Pleistocene magnetostratigraphy. However, the top of *R. pseudoumbilicus* (Early Pliocene) always appeared to be older than 3.82 Ma based on the ages suggested by the preliminary magnetostratigraphy. This offset could be explained by an earlier extinction (therefore an older age for this event) or very low abundances of this species towards its last occurrence at this latitude in the North Atlantic. Further investigation of the nannofossil and foraminifera assemblages will help us scrutinise and understand such diachronicities and improve our understanding of the Miocene to Pleistocene North Atlantic biostratigraphy.

References

Martini, E. 1971. Standard Tertiary and Quaternary calcareous nannoplankton zonation. *In*: A. Farinacci (Ed.). *Proceedings of the 2nd International Conference on Planktonic Microfossils, Roma* **2**:739–785.

Raffi, I., Wade, B.S. & Pälike, H. 2020. The Neogene Period (Chapter 29). *In*: F.M. Gradstein, J.G. Ogg, M.D. Schmitz & G.M. Ogg (Eds). *Geological Time Scale 2020* **2**:1141–1215.

Cretaceous–Paleogene calcareous nannofossils from International Ocean Discovery Program Expedition 392 to the Agulhas Plateau, south-western Indian Ocean

Denise K. Kulhanek
Institute of Geosciences, Christian-Albrechts-University of Kiel, Ludewig-Meyn-Straße 10–14, 24118 Kiel, Germany; denise.kulhanek@ifg.uni-kiel.de

Odysseas A. Archontikis
Department of Earth Sciences, University of Oxford, South Parks Road, Oxford OX1 3AN, UK

Jens O. Herrle
Institute of Geosciences, Goethe-University Frankfurt, Altenhoeferallee 1, 60438 Frankfurt am Main, Germany

Peter K. Bijl
Department of Earth Sciences, Utrecht University, Princetonlaan 8A, 3584 CB Utrecht, Netherlands

Ashley M. Burkett
Boone Pickens School of Geology, Oklahoma State University, 103C, 105 Noble Research Center, Stillwater, OK 74078, USA

Jason J. Coenen
Geology and Environmental Geosciences, Northern Illinois University, Davis Hall 312, 218 Normal Road, DeKalb, IL 60115, USA

Edoardo Dallanave
Department of Geosciences, University of Bremen, Klagenfurter Straße 2-4, 28359 Bremen, Germany

Courtney J. Sprain
Department of Geological Sciences, University of Florida, 241 Williamson Hall, Gainesville, FL 32611, USA

Sietske J. Batenburg
Department of Earth and Ocean Dynamics, University of Barcelona, Martí i Franqués, 08028 Barcelona, Spain

Thomas Westerhold
MARUM, Center for Marine Environmental Sciences, University of Bremen, Leobener Straße 8, 28359 Bremen, Germany

Gabriele Uenzelmann-Neben
Department of Geosciences, Geophysics Section, Alfred Wegener Institute, Helmholtz Center for Polar and Marine Research, Am Alten Hafen 26, 27568 Bremerhaven, Germany

Steven M. Bohaty
Institute of Earth Sciences, Heidelberg University, Im Neuenheimer Feld 234-236, 69120 Heidelberg, Germany

Laurel Childress
International Ocean Discovery Program, Texas A&M University, 1000 Discovery Drive, College Station, TX 77845, USA

IODP Expedition 392 Scientific Party

International Ocean Discovery Program (IODP) Expedition 392 cored three sites on the Agulhas Plateau and one site in the Transkei Basin to address questions regarding the origin and timing of the emplacement of the Agulhas Plateau, as well as to examine Southern Ocean climate history and the opening of oceanic gateways from the Cretaceous through the Paleogene. The age models for the sites relied primarily on calcareous nannofossils and magnetostratigraphy, with dinoflagellates providing key events for some intervals, and additional constraints from planktonic foraminifera and diatoms. Site U1579, located in a depression on the central Agulhas Plateau, recorded a nearly continuous section dated Santonian to earliest Miocene. Dinoflagellates provided the age control for the zeolitic sandstone and siltstone with glauconite at the base of the cored section. Above this, nannofossils were common to abundant and moderately preserved in the Upper Santonian to Maastrichtian calcareous chalks, with the assemblages showing Southern Ocean affinities. Paleogene nannofossils were abundant and moderately to well preserved. Sedimentation rates were the lowest in the Eocene, which included either condensed intervals or hiatuses. Nannofossils were well preserved in the Oligocene,

with the assemblages consisting of primarily mid-latitude species with occasional incursions of cold-water taxa. Site U1580 was located on the southern Agulhas Plateau, adjacent to a basement high. Cretaceous–Cenozoic sedimentation at this site was interrupted by several unconformities, and the lowermost part of the cored interval was interspersed with basalt layers interpreted as sills. The oldest sediment was likely uppermost Cenomanian in age. Overlying the shallowest basalt were a Coniacian–Santonian silt- and sandstone with varying proportions of zeolites, glauconite and carbonate. Sedimentation rates were very high (~10 cm/kyr) during this time. Much of the Lower Campanian and mid-Maastrichtian were missing at this site. The Paleocene nannofossils were moderately well preserved and suggested a continuous section with sedimentation rates of 1.5 cm/kyr. The sedimentation rates increased in the Late Paleocene to Early Eocene, and nannofossils were quite well preserved through the Paleocene–Eocene Thermal Maximum and in the Lower Eocene chalk/ooze. Site U1581 in the Transkei Basin included a thick section of Upper Campanian to Maastrichtian mudstone with occasional sandstone beds. Nannofossils were sparse, but very well preserved through much of this interval, although the preservation decreased with depth, concomitant with increasing siderite. The Cretaceous assemblages included both Southern Ocean and mid-latitude taxa. Reworking was common throughout the Cenozoic and this interval was also interspersed with hiatuses, especially in the Eocene and Miocene. Sedimentation appears to have been more continuous from the latest Miocene to the present, with sedimentation rates of ~2.8 cm/kyr. Site U1582, cored on the northern Agulhas Plateau, included only ~40 m of ooze and siliciclastic sediments overlying the basement. Manganese nodules were common, and the section was highly condensed, with at least 70 Myr represented. Future work will refine the age models for each site to provide a framework for the palaeoclimatic and palaeoceanographic studies planned by the expedition science party members.

Distinct physiological responses of *Coccolithus braarudii* life-cycle phases to light intensity and nutrient availability

Gerald Langer
Institute of Environmental Science and Technology (ICTA), Universitat Autònoma de Barcelona (UAB), 08193 Bellaterra, Spain; Gerald.Langer@uab.cat

Vun Wen Jie, Dorothee Kottmeier, Serena Flori, Daniela Sturm, Joost de Vries
The Marine Biological Association of the United Kingdom, The Laboratory, Citadel Hill, Plymouth PL1 2PB, UK

Glenn M. Harper
Plymouth Electron Microscopy Centre, Brunel, Drake Circus, Plymouth PL4 8AA, UK

Colin Brownlee, Glen Wheeler
The Marine Biological Association of the United Kingdom, The Laboratory, Citadel Hill, Plymouth PL1 2PB, UK

Coccolithophores feature a haplo-diplontic life-cycle comprised of diploid cells producing heterococcoliths and haploid cells producing morphologically different holococcoliths. These life-cycle phases of each species appear to have distinct spatial and temporal distributions in the oceans, with the heavily calcified heterococcolithophores (HET) often being more prevalent in winter and at greater depths, whilst the lightly calcified holococcolithophores (HOL) are more abundant in summer and in shallower waters. The haplo-diplontic life-cycle may therefore allow coccolithophores to expand their ecological niche, switching between life-cycle phases to exploit conditions that are more favourable. However, coccolithophore life-cycles remain poorly understood, and fundamental information on the physiological differences between life-cycle phases is required if we are to better understand the ecophysiology of coccolithophores. In this study, we have examined the physiology of the HET and HOL phases of the coccolithophore *Coccolithus braarudii* in response to changes in light and nutrient availability. We found that the HOL phase was more tolerant to high light intensity than the HET phase, which exhibited defects in calcification at high irradiances. The HET phase exhibited defects in coccolith formation under both nitrate and phosphate limitation, whilst no defects in calcification were detected in the HOL phase. The HOL phase grew to a higher cell density under phosphate-limitation than nitrate-limitation, whereas no difference was observed in the maximum cell density reached by the HET phase at these nutrient concentrations. The HET cells grown under a light:dark cycle divided primarily in the dark and in the early part of the light phase, whereas the HOL cells continued to divide throughout the 24-h period. The physiological differences may contribute to the distinct biogeographical distributions observed between the life-cycle phases, with the HOL phase potentially being better adapted to high-light, low-nutrient regimes, such as those found in seasonally stratified surface waters.

Oceanic temperature and pCO_2 reconstruction during the Pliocene in the Caribbean Sea (ODP Site 999) using coccolith geochemistry

Goulwen Le Guevel, Fabrice Minoletti
Sorbonne Université, ISTeP, Paris, France; goulwen.le_guevel@sorbonne-universite.fr
Michael Hermoso
Université du Littoral Côte d'Opale, Laboratoire d'Océanologie et de Géosciences, Wimereux, France

The Pliocene (5.33–2.58 Ma) is one of the key periods cited by the IPCC as a geological analogue of anthropogenic climate change. The global climate during this period was indeed comparable with modelling predictions for the near future—sea-surface temperatures (SSTs) were 3ºC warmer than today and atmospheric pCO_2 was 1 to 1.5 times higher than preindustrial values.

These two major climate parameters (SSTs and pCO_2) are usually assessed using proxies involving measurements made on both the organic matter produced by coccolithophores (alkenones) and the calcite of foraminiferal tests. Our approach was to use a unique archive—the coccoliths—for the determination of both SSTs and pCO_2. Coccoliths are a very promising substrate to analyse for palaeoclimatic studies because they calcify in the uppermost water-column and because their isotopic ratios are sensitive to both photosynthesis and calcification (Hermoso et al., 2016). Therefore, these isotopic ratios give us physiological and metabolic information about coccolithophores of the past.

After microseparation of the coccoliths into various size fractions (Minoletti et al., 2009), we used oxygen isotopic ratios for the SST calculations. We also derived pCO_2 from the difference in $\delta^{13}C$ between the small and large coccoliths fractions following a recently calibrated CO_2 proxy (Godbillot et al., 2022).

The results obtained from samples spanning the entire Pliocene interval (ODP 999A, Kogi Rise in the Caribbean Sea at 13ºN and DSDP Site 516, Rio Grande Rise in the South Atlantic at 30ºS) showed an increase in SSTs between 5 and 4 Ma in the Caribbean Sea from 26 to 31ºC, in contrast to results from the south-eastern Atlantic, where the surface waters freshened during that period. From 4 to 2.5 Ma, both temperature trends were reversed, with a notable decrease in SSTs in the Caribbean Sea from 31 to 27ºC. This is consistent with published results (Karas et al., 2017). Our pCO_2 values are in agreement with published datasets (Rae et al., 2021) and show small variations throughout the Pliocene (between 310 and 375 ppmv in the whole interval). These results confirm that the biogeochemistry of coccoliths has a great potential for deep-time palaeoclimate reconstruction.

References

Godbillot, C., Minoletti, F., Bassinot, F. & Hermoso, M. 2022. Parallel between the isotopic composition of coccolith calcite and carbon levels across Termination II: Developing a new paleo-CO_2 probe. *Climate of the Past*, **18**: 449–464.

Hermoso, M., Chan, I.Z.X., McClelland, H.L.O., Heureux, A.M.C. & Rickaby, R.E.M. 2016. Vanishing coccolith vital effects with alleviated carbon limitation. *Biogeosciences*, **13**: 301–312.

Karas, C., Nürnberg, D., Bahr, A., Groeneveld, J., Herrle, J.O., Tiedemann, R. & deMenocal, P.B. 2017. Pliocene oceanic seaways and global climate. *Scientific Reports*, **7**: 39842.

Minoletti, F., Hermoso, M. & Gressier, V. 2009. Separation of sedimentary micron-sized particles for palaeoceanography and calcareous nannoplankton biogeochemistry. *Nature Protocols*, **4**: 14–24.

Rae, J.W.B., Zhang, Y.G., Liu, X., Foster, G.L., Stoll, H.M. & Whiteford, R.D.M. 2021. Atmospheric CO_2 over the past 66 million years from marine archives. *Annual Review of Earth and Planetary Sciences*, **49**: 609–641.

Evolution of Miocene calcareous nannofossil assemblages and palaeoceanographic research on the South China Sea

Chuanlian Liu, Guanyu Lin, Ruixue Gong, Hui Zhang
State Key Laboratory of Marine Geology, Tongji University, Shanghai 200092, China; liucl@tongji.edu.cn

We will present Miocene calcareous nannofossil biostratigraphic events, assemblages and morphological parameters from International Ocean Discovery Program (IODP) Site 1501 in the northern South China Sea. Firstly, we divided the strata using the biostratigraphic events of the Miocene to determine the depth–time relationship. Secondly, we quantified the Miocene nannofossil assemblages, including the ratio of the abundance of nutrient-rich and nutrient-poor species (*N ratio*) to reconstruct the marine palaeoproductivity. In the Miocene, the periods of high productivity were 23–12.5 Ma and 6–5 Ma, while the period of low productivity was 12.5–6 Ma. Interestingly, there was local low productivity at 16–14.5 Ma, while local productivity was high 9.9–8.8 Ma. In addition, we compared the *N ratio* of the calcareous nannofossils with global phenomena, such as biogenic blooms, carbon isotope shifts and the carbonate crash in the Miocene. It was found that the biogenic bloom period shows good correspondence with the *N ratio* 6–5 Ma and 9.9–8.8 Ma, with the *N ratio* indicating high productivity environments at these times. The carbon isotope ratio of seawater was continuously heavier 23–16 Ma, when the *N ratio* indicated high productivity. At 13.5–6 Ma, the carbon isotope ratios were continuously lighter, while the *N ratio* indicated low productivity. Therefore, there is a clear correlation between marine productivity and the carbon isotope signal. At 9.9–8.8 Ma, a carbonate crash was indicated by a significant decrease in the carbonate content in the sediments. At the same time, the *N ratio* suggested a nutrient-rich environment. We also quantified changes in the Miocene coccolith morphological parameters, including length, thickness and weight, which all showed very similar patterns. The morphological parameters often had lower values when the *N ratio* was higher. Thus, a high-productivity environment may lead to smaller, thinner and lighter coccolith morphologies. In comparing reconstructions of atmospheric CO_2 concentrations with coccolith morphology, it was found that atmospheric CO_2 concentrations peaked during the Middle Miocene Climatic Optimum (MCO), at which time, coccolith length was at its shortest. On the whole, coccolith length is negatively correlated with atmospheric CO_2 concentrations. This may be because a high concentration of atmospheric CO_2 promotes the dissolution of coccoliths, but it is worth noting that atmospheric CO_2 concentrations were higher in the Early Miocene, and coccolith length tended to be longer at that time. This shows that atmospheric CO_2 may also promote calcification when atmospheric CO_2 concentrations are moderate.

The Lorca Basin revisited: How integrated stratigraphy can help resolve long-standing controversies

Francesca Lozar, Enrico Nallino, Gabrielle Viggiani
Department of Earth Sciences, Università degli Studi di Torino, Torino, Italy; francesca.lozar@unito.it

Hugo Corbí Sevila, Jesus Soria Mingorance
Department of Earth and Environmental Sciences, Universidad de Alicante, Spain

Alan Deino
Berkeley Geochronology Center, Berkeley, CA, USA

Luis Gibert Beotas
Department of Mineralogy, Petrology and Applied Geology, Universidad de Barcelona, Spain

Evaporitic deposition was widespread and voluminous during the Late Miocene in the Mediterranean Basin. These deposits can be correlated regionally to marginal basins with strikingly similar depositional ages. However, the age of the Upper Miocene sediments of the Lorca Basin in southern Spain remains controversial, with the pre-evaporitic and evaporitic deposits having been variously assigned to the Tortonian and the Messinian.

We performed an integrated study of the Varied Member of the Serrata Formation from the La Serrata section, based on sedimentology, calcareous plankton micropalaeontology, magnetostratigraphy and radiochronology. Preliminary data indicate that the succession was deposited during the Messinian on the basis of the calcareous nannofossil and foraminifera assemblages.

The finding of *Reticulofenestra rotaria* from the base of the Varied Member indicates an age not greater than 7.4 Ma. The first consistent occurrence, in the middle part of the section, of *Turborotalita multiloba* (an endemic Messinian foraminiferal taxon) concurrently with *Neogloboquadrina acostaensis* (sinistral coiling) in an interval with reverse magnetic polarity suggests a correlation with the UA15–17 cycles identified by Sierro et al. (2001) in the Perales section (Sorbas Basin, Spain). Two dispersed tephra layers identified at the base of the section contained volcanic glass and a mineral assemblage suitable for $^{40}Ar/^{39}Ar$ dating. These layers occur just below the occurrence of *Turborotalita multiloba* and the $^{40}Ar/^{39}Ar$ dating of these tuffs is underway to test this age interpretation.

The available data permit a reconstruction of the characteristics of the water-column immediately before the deposition of the gypsum of the Messinian Salinity Crisis. The environment was evidently eutrophic, as also suggested by a great abundance of diatoms.

Nutrient forcing on the late Middle Eocene to Early Oligocene (~40–31 Ma) evolution of the coccolithophore *Reticulofenestra* (Order Isochrysidales)

Ruigang Ma
State Key Laboratory of Marine Geology, Tongji University, Shanghai, China; maruigang@tongji.edu.cn
Marie-Pierre Aubry
Department of Earth and Planetary Sciences, Rutgers University, New Brunswick, NJ, USA
David Bord
Ellington Geological Services, 1414 Lumpkin Road, Houston, TX 77043, USA
Chuanlian Liu
State Key Laboratory of Marine Geology, Tongji University, Shanghai, China

The first size reduction (FSR) in coccolithophores of the Order Isochrysidales, which occurred in the Early Oligocene (~32 Ma), is of great significance for understanding the Lilliput effect that has affected all coccolithophores from the Late Eocene to this day, and is generally interpreted as reflecting a global pCO_2 decline. Here, we offer a complementary mechanism based on the results of a comprehensive morphometric analysis of the coccoliths of *Reticulofenestra* species that lived during late Middle Eocene to Early Oligocene (~40–31 Ma), using marine sediments from the South Atlantic Ocean. The results show increased size and decreased abundance of the large group during the Late Eocene and Early Oligocene, leading to the disappearance of large *Reticulofenestra*s at the FSR and a concurrent decrease in the size variability of the small to medium coccoliths, in which the diameter of the central opening had become very reduced. We have interpreted these results in light of an ecological model designed to link coccolith morphology and trophic strategy. In sunlit oceanic waters, the small- to medium-sized, r-selected coccolithophores with smaller central openings lived in deeper, nutrient-rich waters, where they did not rely much on mixotrophy. The larger, K-selected species with larger central openings lived in the oligotrophic surface waters where they strongly relied on mixotrophy. On this basis, we propose that the FSR is the mid-term result of the environmental destabilisation that occurred at ~35.5 Ma, caused by the expansion of eutrophic environments following the establishment of overturning circulation in the Atlantic Ocean.

Coccolithophore physiology and molecular mechanism response to the seawater Mg/Ca ratio

Xiaoxu Ma, El Mahdi Bendif, Craig Dedman, Rosalind E.M. Rickaby
Department of Earth Sciences, University of Oxford, South Parks Road, OX1 3AN, UK; xiaoxu.ma@exeter.ox.ac.uk

Coccolithophores are calcifying unicellular phytoplankton that are sensitive to environmental change. As the most ubiquitous ion and nutrient element, Mg^{2+} is essential for enzyme functionalisation, ion homeostasis and photosynthesis. In addition, Mg also has the potential to inhibit mineral growth in inorganic calcite and raises the saturation state needed for the precipitation of calcite. The primary mineralogy of inorganic carbonates in the high-Mg/Ca modern ocean is aragonite. It is unknown, however, whether an increasing Mg content in the ocean relative to Ca, as has occurred over the last 60 million years, may also interfere with calcite biomineralisers, particularly coccolithophores, which calcify intracellularly and have reduced in size over this same time-scale.

Through this study, we are aiming to have a comprehensive understanding of the Mg concentration interference with coccolithophore physiology and calcification abilities. We cultured six strains that represent four coccolithophore species, including over-calcified and regularly-calcified *Gephyrocapsa huxleyi*, *G. oceanica*, *Coccolithus braarudii* and *C. pelagicus*, under a range of Mg/Ca ratios. For the physiology response, we evaluated their cell adaptation and calcification sensitivities under different Mg concentrations by measuring the growth rate, chlorophyll concentration, morphology and calcification level. For all strains, we found that the lowest Mg/Ca ratio could limit growth, with no significant malformations observed in the coccoliths. *Gephyrocapsa huxleyi* strains appeared to exert the strongest control over the chemistry at the site of calcification, as they were still able to calcify under extreme Mg concentrations. However, more malformed and incomplete coccoliths were observed with increasing Mg. *Gephyrocapsa oceanica* can maintain its calcification ability across the Mg/Ca range, except under extremely high Mg concentrations. *Coccolithus* spp. were more vulnerable than other species because their growth was more reduced at medium Mg/Ca ratios, reaching complete growth inhibition at higher Mg concentrations. To understand the molecular mechanism behind the physiological adaptation, we assessed the stoichiometry of one strain of *G. huxleyi*. We found that the Mg/Ca ratio in cells increased simultaneously with a rise in the ambient Mg/Ca ratio, while the Mg partitioning coefficient decreased. The elemental composition of this strain reflected its malformation status and chlorophyll content. Further proteomic analysis will be performed in order to examine the detailed molecular mechanism of different calcification abilities in *G. huxleyi*.

Oligo-monospecific assemblage of calcareous nannoplankton in response to the Messinian palaeoceanographic setting: Insights from the Monte dei Corvi section (central Italy)

Alan Maria Mancini, Francesca Lozar, Rocco Gennari
Dipartimento di Scienze della Terra, Universita degli Studi di Torino, Torino, Italy; alanmaria.mancini@unito.it
Savannah Myers, Alessandra Negri
Dipartimento di Scienze della Vita e dell'Ambiente, Università Politecnica delle Marche, Ancona, Italy

During the Messinian, tectonic uplift in the palaeo-Gibraltar Strait resulted in a progressive reduction in water exchange between the Atlantic and the Mediterranean, promoting a sluggish thermohaline circulation and resulting in periodic oxygen starvation at the seafloor. Before the Messinian Salinity Crisis (MSC, 5.97–5.33 Ma), the hemipelagic sedimentation in the Mediterranean Basin was controlled by changes in Earth's orbital parameters, and was usually characterised by the rhythmic deposition of organic-rich marls, intercalated with white marls, diatomites or limestones. The organic-rich marls, often termed 'sapropels', were thought to be deposited during precession-minima phases (insolation maxima), when the seafloor suffered oxygen deficiency. A clear example of precession-driven sedimentation crops out in the Monte dei Corvi section (Ancona, central Italy), where sapropels are intercalated with white limestones. Here, we present a high-resolution study of calcareous nannofossils (CN), coupled with a petrographic investigation, conducted over four sedimentary cycles (from 6.55 to 6.48) of the Monte dei Corvi section, in order to better constrain the palaeoceanographic conditions that promoted the deposition of the sapropels and limestones. The CN assemblage recorded in the sapropels is dominated by taxa (*Discoaster* spp. and *Sphenolithus* spp.) that were able to proliferate in the lower photic zone, when the nutricline shoaled in the photic zone and a deep chlorophyll maximum occurred. The sapropels are finely laminated, with abundant small pyrite inclusions and lacking macrobioturbation. Both the micropalaeontological and petrographic features point to a strongly stratified water-column during the sapropel deposition, a condition that prevented oxygen diffusion at the seafloor through thermohaline circulation. Conversely, the limestone beds were nannofossil oozes, characterised by either oligospecific or monospecific CN assemblages, composed of *Umbilicosphaera jafari* and/or *Reticulofenestra antarctica* and/or *Calcidiscus leptoporus*. The limestone beds are finely laminated, especially at the top, and the lamination is made by the alternation of white (fecal pellets with nannofossils) and brown (mainly terrigenous) laminae. The low diversity of the CN assemblages in the limestone deposits suggests extreme environmental conditions in the upper water-column, probably related to high salinity, colder temperatures and eutrophication. Therefore, we infer that the limestone beds were deposited in response to a recovery of the mixing processes in the photic zone, which stimulated CN productivity and exported their remains to the seafloor. A detailed comparison with CN assemblages of about the same age, reported from south-eastern Spain (Sorbas Basin), indicated the same features, but occurring in different lithofacies. These findings suggest that the palaeoceanographic conditions responsible for the sapropel deposition differed across the various Mediterranean sub-basins. Indeed, in the Sorbas Basin, the onset of the sapropel coincides with a precession-driven cold phase. The conclusions reached could be useful for better constraining, and potentially predicting, the Mediterranean deoxygenation trend in response to current climate change.

Calcareous nannofossils across the Campanian–Maastrichtian high-productivity system of Aderet, Shefela Basin, Israel

Sara Marconato, Sigal Abramovich
Ben Gurion University of the Negev, Israel; saramarc@post.bgu.ac.il
Nicolas Rudolph Thibault
IGN, University of Copenhagen, Øster Voldgade 10, DK-1350, Copenhagen, Denmark
Sarit Ashckenazi-Polivoda
Dead Sea and Arava Science Center, Israel

In the Late Cretaceous, the Levant area was characterised by a large upwelling zone, as now witnessed by the organic-rich carbonates of the Mishash and Ghareb Formations. Previous stratigraphical and palaeoceanographical studies of the Campanian to Maastrichtian deposits in this area showed prominent facies variation, from fully oxygenated to anoxic conditions across N–S and E–W transects. The Aderet core was drilled in the depocenter of the Shefela Basin, Israel, considered to be a deeper distal position in the upwelling belt. Because the Aderet core has so far delivered unique tropical sea-surface temperature reconstructions for the Santonian to Maastrichtian, based on TEX^{86}, this core requires a precise stratigraphic framework and age-model. Until now, the stratigraphy and age-model had been based on foraminifera only, but the position of the Campanian/Maastrichtian boundary remained unclear. Here, we present the calcareous nannofossil biostratigraphy of the Aderet borehole at a resolution of 5 m—approximately equivalent to that used for the planktonic foraminifera. Due to the high percentages of total organic carbon (TOC), varying between 5 and 20%, we adopted a protocol to oxidise the organic matter prior to preparing the nannofossil slides. A comparison between slides made with and without the adopted protocol showed that the protocol significantly improved the abundances and observation of the nannofossils.The core can be ascribed to CC20 to CC25a *sensu* Perch Nielsen (1985) and UC14b to UC19 *sensu* Burnett et al. (1998). Our study allowed us to revise the previous age-model by integrating the calcareous nannofossil and planktonic foraminifera biohorizons, and using the Bacon modelling approach. Accordingly, the age of the borehole extended from 79.2 Ma to 69.4 Ma and the Campanian/Maastrichtian boundary was significantly revised to a depth between 361 m, close to the base of *Pseudoguembelina palpebra*, and 332 m, near the top of *Uniplanarius trifidus* (in contrast to previous studies that positioned this boundary at 452 m). In addition, preliminary palaeoecological results confirm the constant presence of eutrophic to mesotrophic calcareous taxa (*Biscutum constans*, *Placozygus fibuliformis*, *Zeugrhabdotus* group, *Cervisiella saxea*) and delineate a response to the general cooling trend of the Late Campanian–Early Maastrichtian, expressed by increases in *Arkhangelskiella cymbiformis*, *Ahmuellerella octoradiata*, *A. regularis*, *Cribrosphaerella ehrenbergii*, *Prediscosphaera cretacea* and *Micula staurophora* and changes in biodiversity.

References

Ashckenazi-Polivoda, S., Titelboim, D., Meilijson, A., Almogi-Labin, A., & Abramovich, S. 2018. Bathymetric trend of Late Cretaceous southern Tethys upwelling regime based on benthic foraminifera. *Cretaceous Research*, **82**: 40–55.

Burnett, J.A. 1998. Upper Cretaceous. *In*: P.R. Bown (Ed.). *Calcareous nannofossil biostratigraphy*. London: Chapman and Hall, 132–199.

Eshet, Y. & Moshkovitz, S. 1995. New nannofossil biostratigraphy for Upper Cretaceous organic-rich carbonates in Israel. *Micropaleontology*, 321–341.

Meilijson, A., Ashckenazi-Polivoda, S., Illner, P., Speijer, R.P., Almogi-Labin, A., Feinstein, S. & Abramovich, S. 2018. From phytoplankton to oil shale reservoirs: A 19-million-year record of the Late Cretaceous Tethyan upwelling regime in the Levant Basin. *Marine and Petroleum Geology*, **95**: 188–205.

Perch Nielsen, K. 1985. *Mesozoic calcareous nannofossils*. *In*: H.M. Bolli, J.B. Saunders & K. Perch-Nielsen (Eds). *Plankton stratigraphy: Volume 1. Planktonic foraminifera, calcareous nannofossils and calpionellids*. Cambridge: Cambridge University Press.

Shawar, L., Halevy, I., Said-Ahmad, W., Feinstein, S., Boyko, V., Kamyshny, A. & Amrani, A. 2018. Dynamics of pyrite formation and organic matter sulfurization in organic-rich carbonate sediments. *Geochimica et Cosmochimica Acta*, **241**: 219–239.

Messinian–Pliocene chronostratigraphy and palaeoceanography of IODP Site 1387: The calcareous nannofossil washing–winnowing effect

Laura Martín García, José-Abel Flores, Francisco J. Sierro
Department of Geology, University of Salamanca, Salamanca, Spain; lauramaga@usal.es

Barbara Balestra
American University, Environmental Science Department, 20016 Washington DC, USA & National Museum of Natural History, Smithsonian, Paleobiology Department, 20560 Washington DC, USA & University of California, Santa Cruz, Institute of Marine Sciences, 95064 Santa Cruz, CA, USA

The Messinian Salinity Crisis was one of the most important episodes in the history of the Mediterranean, with a relevant impact on the ocean, particularly in the Atlantic. From Miocene–Pliocene material retrieved from IODP Site 1387, located in the Gulf of Cádiz, we performed a biostratigraphical review and an environmental reconstruction, taking into account surface water temperatures, nutrient availability and productivity.

In the analysed samples, several standard CN biozonation events were identified and calibrated, including the highest occurrence (HO) of *Amaurolithus amplificus*, lowest occurrence (LO) of *Ceratolithus acutus armatus*, LO of *C. cristatus* and LOs of *Discoaster asymmetricus* and *D. tamalis*, allowing us to refine the previous biostratigraphy.

Additionally, we realised a sedimentological study on the core, identifying washing–winnowing episodes in samples resulting from contour currents. These samples were characterised by abrupt decreases in the nannofossil content and an increase in sand-sized particles. The most relevant washing–winnowing episode was dated at between 5.62 and 5.38 Ma, coinciding with the end of the Messinian Salinity Crisis.

This preliminary study allows us to conclude that, during the Late Messinian in the Gulf of Cadiz, the surface waters were warm and oligotrophic, related to the Mediterranean–Atlantic disconnection during the salinity crisis. Curiously, our data indicate that contourite currents were also produced during the salinity crisis. Later, during the Pliocene, the surface-waters were colder and eutrophic, as a result of the Mediterranean–Atlantic connection.

Weakening of the biological pump induced by a nannoplankton crisis during the Early Toarcian Oceanic Anoxic Event

Wolfgang Ruebsam

Department of Organic and Isotope Geochemistry, Institute of Geoscience, University of Kiel, Germany

Emanuela Mattioli

Université Lyon, UCBL, ENSL, UJM, CNRS, UMR 5276 LGL-TPE, F-69622 Villeurbanne, France, & Institut Universitaire de France, Paris, France; emanuela.mattioli@univ-lyon1.fr

Lorenz Schwark

Department of Organic and Isotope Geochemistry, Institute of Geoscience, University of Kiel, Germany & WA-OIGC, Curtin University, Perth, Australia

Severe environmental changes occurred during the Early Toarcian (Early Jurassic, ~183 Ma) related to the rising atmospheric CO_2 concentration and associated changes in ocean alkalinity and seawater temperatures. Such perturbations directly or indirectly (i.e. via ocean-water stratification and nutrient delivery to the surface waters) impacted the marine primary producers. Changes in the phytoplankton community structure, in turn, affected the marine food web, the biological pump and thereby the entire marine ecosystem and carbon cycling. Recently, this scenario has been challenged thanks to the recovery in sediments of imprints of coccoliths on organic materials, originating from the dissolution of $CaCO_3$ due to the presence of high amounts of organic matter leading to acidic pore waters during diagenesis.

We show here new data from the core FR-210-078 (Lorraine Basin), where rather low organic carbon accumulation rates have been estimated. This observation is substantiated by a reduced export efficiency of organic carbon to the sediment, caused by a drastic decline in the abundance of mineral ballast (i.e. nannoplankton-derived calcite), due to a major decrease in the calcification potential of the coccolithophores, and in calcareous nannofossil fluxes. Besides this decline in primary carbonate production, a drop in both abundance and size was documented for the fecal pellets. A net reduction in mineral (i.e. calcite) ballast led to weakening of the sinking speed of particulate organic matter that then became more prone to biodegradation. The reduced organic-carbon accumulation rates are here interpreted as reflecting a weakening of the biological pump. These new data substantiate the role of organic-matter preservation as a major factor controlling the formation of black shales during the Early Toarcian, as well as the key role played by calcareous nannoplankton in the carbon cycle during past dramatic climatic events.

The coccolithophore community of the Sargasso Sea

Josué G. Millán, Amos Winter
Indiana State University, Terre Haute, Indiana, USA; jmillan1@sycamores.indstate.edu
Richard W. Jordan
Yamagata University, Yamagata, Japan
Jeremy R. Young
University College London, London, UK
Leocadio Blanco-Bercial, Rod Johnson
Bermuda Institute of Ocean Sciences, St. Georges, Bermuda

The Sargasso Sea is a dynamic region in the North Atlantic Ocean, delimited by the western boundary current that forms part of the North Atlantic Gyre, and is often depicted as an oligotrophic environment. In the Sargasso Sea, most of the primary production occurs between 80 and 120 m, at the deep chlorophyll maximum (DCM). The haptophytes, a clade of algae that share a common evolutionary ancestor, represent the main group of eukaryotes in the Sargasso Sea, as detected by total integrated Chl-a biomass. From this group, coccolithophores are arguably the best-known organisms due to their contribution to global carbon cycles as key calcifying primary producers. Hence, multiple projects around the world have been carried out to study coccolithophore communities from disparate locations, usually based on cruises of opportunity, such as latitudinal oceanic transects across the Atlantic Ocean close to the Mid-Atlantic Ridge. This has created a disproportionate dataset, which is often used to represent the entire ecosystem. On the western side of the North Atlantic, research on phytoplankton communities has been undertaken at the Bermuda Atlantic Time-series (BATS) stations by various groups, but not to the level of the taxonomic identification of the coccolithophores, which we remedy in this presentation. Our examinations, as part of a short study focusing on the lower photic zone, of samples collected from Hydrostation S show a high biodiversity not previously reported. We found that the BATS coccolithophore community during the fall of 2020 comprised 206 morphotypes, of which 90 were present at 20 m depth, and 182 in the lower photic zone (DCM and below). Of those, at least 40 morphotypes were completely new to science or undescribed.

Separation of coccoliths from sediments: An automated protocol for palaeoclimatic investigations

Fabrice Minoletti
Sorbonne Université, Institut des Sciences de la Terre de Paris (UMR 7193 ISTeP), Paris, France; fabrice.minoletti@sorbonne-universite.fr

Michaël Hermoso
Université du Littoral Côte d'Opale, Laboratoire d'Océanologie et de Géosciences (UMR 8187 LOG), Wimereux, France

Camille Godbillot
Previously Sorbonne Université, Institut des Sciences de la Terre de Paris (UMR 7193 ISTeP), Paris, France & now CEREGE (UMR 7330), CNRS, Aix-Marseille Université, IRD, College de France, INRA, Aix-en-Provence, France

Goulwen le Guevel
Sorbonne Université, Institut des Sciences de la Terre de Paris (UMR 7193 ISTeP), Paris, France

Maxime Tremblin
Previously Sorbonne Université, Institut des Sciences de la Terre de Paris (UMR 7193 ISTeP), Paris, France & now Department of Earth Sciences, Université de Genève, Genève, Switzerland

Palaeoclimatic reconstructions are commonly based on geochemical data measured on manually isolated planktonic foraminifera. These tests are often affected by diagenetic overgrowth and recrystallisation (frosty vs glassy tests) that may obliterate the original palaeoenvironmental signal sought. In addition, uncertainties remain about the calcification depth recorded during the vertical migration of foraminifera within the water-column. The analysis of coccoliths has a great potential to avoid such caveats because they are produced by autotrophic algae in the uppermost water-column and their intricate ultrastructures limit significant overgrowth. However, their tiny dimensions, which prevent manual isolation, have limited their use in palaeoceanography, although this has motivated considerable efforts in the development of protocols allowing their targeted analysis.

By using cascade filtering steps on polycarbonate membranes with well-calibrated pores, coccoliths may be split into distinct fractions (Minoletti et al., 2009). A large variety of geochemical and morphometric proxies can be applied to the separated fractions to assess palaeoenvironmental parameters, such as sea-surface temperatures and CO_2 levels. Recent developments allow the protocol to be applied automatically by using various electronic components (water level detectors, DC motors and pumps) in order to reduce the duration of the process and run multiple samples in parallel. This protocol has been applied in different sedimentary contexts and time periods, spanning from the Toarcian to the Pleistocene, and forms the technical underpinning of several other studies presented at INA18.

References

Minoletti, F., Hermoso, M. & Gressier, V. 2009. Separation of sedimentary micron-sized particles for palaeoceanography and calcareous nannoplankton biogeochemistry. *Nature Protocols*, **4**: 14–24.

Surface-water variations during the Middle and Late Pleistocene in the Mozambique Channel based on calcareous nannofossil assemblages

Haley Mossell
Department of Geology and Geophysics, Texas A&M University, Halbouty Building, 3115 TAMU, 611 Ross St., College Station, TX 77843, USA; haley.moss@tamu.edu

Denise K. Kulhanek
Institute of Geosciences, Christian-Albrechts-University of Kiel, Ludewig-Meyn-Straße 10–14, 24118, Kiel, Germany

Gary D. Acton, Leah LeVay
International Ocean Discovery Program, Texas A&M University, 1000 Discovery Drive, College Station, TX 77845, USA

Calcareous nannofossils are what remains of calcareous phytoplankton after they die and find their way to the ocean floor. While these organisms are alive, they record changes in the surface temperature of the ocean. For instance, *Gephyrocapsa oceanica* is strongly linked to warm ocean waters, whereas cooler waters are favoured by *Gephyrocapsa muellerae*. Calcareous nannofossils can also provide information about the availability of nutrients in surface waters. For example, *Gephyrocapsa* spp. (<3 μm) prefer higher nutrient availability. Conversely, *Florisphaera profunda*, a species that lives in the lower photic zone, is only abundant when nutrients are available deep in the water-column, indicating stratified waters and decreased nutrients in the upper photic zone due to an absence of upwelling occurring in the region. Thus, nannofossil assemblages can be used to document how the climate has changed through Earth's history. We examined nannofossil assemblages in samples collected from the piston core MD13-3504, obtained by the R/V *Marion Dufresne* during research cruise MD13 to the Mozambique Channel. The Mozambique Channel is located between the island of Madagascar and Mozambique in East Africa and serves as a path for warm water from the equatorial Indian Ocean to enter the south-western Indian Ocean via the Agulhas Current. The Agulhas Current also injects warm, saline water into the South Atlantic Ocean via the Agulhas leakage, thereby influencing Atlantic meridional overturning circulation. Calcareous nannofossil biostratigraphy, using the appearance of *Emiliania huxleyi* and disappearance of *Pseudoemiliania lacunosa*, indicated that the sediment core was Middle to Late Pleistocene, with the oldest sample examined being from >430 ka. Sea-surface temperatures were generally warm through this time interval, as the nannofossil assemblages were dominated by warm-water taxa, such as *G. oceanica*, *Rhabdosphaera* spp. and *Helicosphaera* spp. Cold-water species, such as *Coccolithus pelagicus* and *G. muellerae* appeared for brief time periods throughout the studied interval. Surface-water stratification increased through time, especially in the interval younger than 290 ka, based on high abundances of *F. profunda* and low N ratio values. These results suggest warmer and more oligotrophic waters dominated in the region over the last ~200 kyr.

Provenance analysis of historic mortars and mortar based materials: A micropalaeontological approach

Joerg Mutterlose, Janina Falkenberg
Institute of Geology, Mineralogy and Geophysics, Ruhr-Universität Bochum, Universitätsstraße 150, 44801 Bochum, Germany; joerg.mutterlose@rub.de

Ulrich Kaplan
Eichenallee 141, 33332 Gütersloh, Germany

Mortar has been the essential construction agent of buildings for more than 9000 years, with lime being the most widely used mortar-binder in historic buildings. To produce lime mortars, naturally occurring limestone is heated to >800ºC, causing a thermal decomposition into quicklime (CaO). Post-Triassic limestones often contain calcareous nannofossils. These calcitic, single-celled, marine photoautotrophic algae (<30 μm) have been significant components of Earth's biogeochemical cycle since the Jurassic and have been, as such, well-studied in the fields of oceanography, marine biology, micropalaeontology and geology. Here, we focus on the neglected application of these algae in archaeology and related fields.

We analysed 28 mortar samples from six archaeologically well-dated medieval churches (800–1510 AD) from the Münsterland Basin (northern Germany) for their calcareous nannofossil content. Notwithstanding substantial heating, most samples yielded low-diversity assemblages, which provided, in some cases, reliable biostratigraphic ages for the limestone. In all examples, locally outcropping limestones were used; in one case, the lime was transported over a distance of 20 km. The medieval builders preferred limestones over marly limestones, even when the latter were exposed closer to the former building site. In the case of Paderborn Cathedral, different limestone resources were used over the 500 years of construction, suggesting that socioeconomic factors (e.g. land ownership) partly controlled the source area of the quarried material.

The general lesson from the current study is that calcareous nannofossils are: 1) present in mortar and mortar-based materials (render, including coloured versions) of historic buildings; and 2) a good tool for the provenancing of mortars (even a few nannofossil findings can suffice).

Emiliania huxleyi biometry and calcification response to environmental gradients in the Indian sector of the Southern Ocean

Shramik Patil, Rahul Mohan
National Centre for Polar and Ocean Research, Goa 403804, India; shramikpatil@gmail.com

Suhas Shetye
National Institute of Oceanography, Goa 403804, India

Vailancy Vaz, Sahina Gazi
National Centre for Polar and Ocean Research, Goa 403804, India

Pallavi Choudhari
Centre for Marine Living Resources and Ecology, Kerala 682508, India

Syed Jafar
National Centre for Polar and Ocean Research, Goa 403804, India

An increase in atmospheric pCO_2 and temperature is expected to reduce ocean CO_3^{2-} concentrations, make oceans warmer and alter ocean circulation patterns. This will also affect the production and biogeographic distribution of marine calcifying organisms, including coccolithophores. The lowering of oceanic CO_3^{2-} is expected to interfere with the coccolithophore calcification process and cause the malformation of coccoliths, whereas changes in oceanic temperatures and circulation patterns may shift their biogeographical boundaries. In this study, we have investigated the *Emiliania huxleyi* coccolith and coccosphere size response to the wide-ranging physicochemical conditions of the Indian sector of the Southern Ocean between 38ºS and 58ºS during the austral summer of 2010 (January–February). This study is helping us to understand the response of the *E. huxleyi* coccolith/coccosphere morphometry and mass changes to the fluctuating temperatures, salinity, CO_3^{2-}, pCO_2 and nutrient values. Our results show that, in the Indian sector of the Southern Ocean, *E. huxleyi* coccoliths were larger and the coccospheres smaller in the Subtropical Zone (STZ). By contrast, the coccolith size was smaller and the coccospheres larger in the Subantarctic Zone (SAZ), due to a decrease in sea-surface temperatures and sea-surface salinity and an increase in nutrient concentrations. In the Indian sector of the Southern Ocean, *E. huxleyi* shows a N–S morphotype shift from the heavily calcified 'Group A' (*E. huxleyi* morphotype A) to the weakly calcified 'Group B' (*E. huxleyi* morphotypes B/C, C) forms. We have demonstrated that, although weakly calcified *E. huxleyi* morphotypes (morphotypes B/C and C) form less mass than *E. huxleyi* morphotype A, due to the large coccospheres and numerous coccoliths per coccosphere, 'Group B' coccospheres precipitate a large amount of $CaCO_3$ in the SAZ compared to Group A coccospheres located in the STZ. We have documented the presence of large, overcalcified *E. huxleyi* coccospheres with large coccoliths in the southernmost cold, high pCO_2 and nutrient-rich waters, which promoted extracellular calcite precipitation. An energy-dispersive spectrometry analysis indicated the presence of a large amount of Mg in the overcalcified *E. huxleyi* specimens. We suspect that, with future projected changes in the carbonate chemistry, the *E. huxleyi* in colder, nutrient-rich waters may adapt to low-pH, high-pCO_2 conditions through extracellular Ca and Mg mineralisation.

Coccolithophore palaeoproductivity in the south-western Atlantic during the last seven terminations

Guilherme Pedrão, Karen Costa, Mariana Tomazella, Rubens Figueira, Bianca Kim, Felipe Toledo

University of São Paulo, São Paulo, Brazil; guilherme.pedrao@usp.br

Glacial terminations are periods that stand out throughout the Quaternary due to their association with abrupt increases in CO_2 concentrations and temperature. In this context, a better understanding of how coccolithophores can respond to such changes is essential, since they are a vital part of the carbon cycle. Here, we investigated variations in coccolithophore palaeoproductivity in the south-western Atlantic Ocean during the last seven terminations, analysing the bulk coccolith fraction Sr/Ca ratios (CF Sr/Ca). Additionally, we compared these results with the relative abundances of species to infer how these organisms and their productivity responded to climatic variations and related oceanographic processes.

The CF Sr/Ca data showed the highest productivity rates during the glacial terminations. The most dominant group during the studied period was *Gephyrocapsa* spp. However, *Florisphaera profunda* and small placoliths were also highly abundant in occasional intervals. Subordinate species (*Helicosphaera* spp., *Coccolithus pelagicus* and *Calcidiscus leptoporus*) were important indicators, appearing in more significant relative abundances during periods of high productivity. Comparisons with estimated sea-surface temperatures suggest the presence of the nutrient-rich South Atlantic central water mass in the lower photic zone, but not reaching the sea surface. This process was associated with variations in seasonality, caused primarily by changes in Earth's orbital cycles. We also noticed changes in benthic foraminiferal assemblages in the same periods as the high coccolithophore productivity. An increase in species that indicate a high organic-matter contribution to the seafloor suggest a benthopelagic coupling, and that at least part of the productivity generated at the surface was being exported to the deep ocean, indicating that coccolithophores played a significant role in the regional carbon cycle.

Late Triassic calcareous nannofossils from Argentina and Peru unravel an early dispersal pathway through Panthalassa

Juan Pablo Pérez Panera

Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET) & División Geología, Museo de La Plata, Facultad de Ciencias Naturales y Museo, Universidad Nacional de Buenos Aires, Pase del Bosque s/n, CP 1900, La Plata, Buenos Aires, Argentina; perezpanera@gmail.com

Calcareous nannofossils first appear in the Middle Norian in the Western Tethys, Northern Calcareous Alps, with the nannolith *Prinsiosphaera triassica* and small unidentified coccolith-like rims (Demangel et al., 2020). The coccolithophores *Crucirhabdus minutus* and *Archaeozygodiscus koessenensis* sporadically appeared after the Late Norian in the same area, and *P. triassica* dispersed to south-eastern Tethys and the eastern Pacific (Bown, 1992; Demangel et al., 2020). By the Early Rhaetian, *Crucirhabdus primulus* and *Eoconusphaera hallstattensis* had first appeared in western and south-eastern Tethys, followed by *Eoconusphaera zlambachensis* (Demangel et al., 2021). In the south-eastern Pacific, recently investigated Late Triassic successions from the Neuquén Basin, Argentina, and the Pucrará Group, north-western Perú, have revealed the presence of *P. triassica* in the Late Norian and Rhaetian and *E. zlambachensis* and *C. minutus* in the Rhaetian (Pérez Panera et al., 2021a, b). These findings correspond to the second record of this group outside the Tethyan Realm, after the finding of *P. triassica* and *C. minutus* in the Norian and Rhaetian in the Queen Charlotte Islands, western Canada (Bown, 1992). Tethyan assemblages have higher species richness and younger records than the eastern Pacific ones, suggesting a Tethyan origin and diversification, and a continuous dispersal through the Panthalassa to the eastern Pacific. According to oceanic circulation models for the Late Triassic, southern easterly cool-water currents may have connect south-eastern Tethys with the south-eastern Pacific, dispersing the calcareous nannoplankton. Once the nannoplankton reached the south-eastern Pacific continental margins, they could disperse to the north, transported by contouritic currents. This hypothesis supposes a permanent connection through the Late Triassic, and could explain the reduced species richness in the eastern Pacific due to a progressive loss in diversity across the dispersal route. Western and south-eastern Tethys, which were connected along continental shelves and were settled at tropical to subtropical latitudes, shared equal species-richness values. A first loss in species richness occurred from south-eastern Tethys to the south-eastern Pacific (Neuquén Basin and Pucará Group), with the absence of *E. hallstattensis*, *A. koessenensis* and *C. primulus* (although this species is later recorded in the Early Jurassic). This loss represented 50% of the species richness and made sense, assuming that this part of the dispersal pathway involved passive transport across the open ocean and by cool-water currents. From the south-eastern Pacific, nannoplankton had a relatively easy path to the Northeastern Pacific. Even so, the loss of species richness continued, given the absence of *E. zlambachensis* from the Queen Charlotte Island sections (Bown, 1992). Although south-eastern and north-eastern Pacific basins were probably continuously connected by continental shelves, the strong equatorial westerly oceanic currents may have acted as an important barrier against dispersion between these areas.

References

Bown, P.R. 1992. Late Triassic–Early Jurassic calcareous nannofossils of the Queen Charlotte Islands, British Columbia. *Journal of Micropaleontology*, **11**(2): 177–188.

Demangel, I., Howe, R., Gardin, S. & Richoz, S. 2021. *Eoconusphaera hallstattensis sp. nov.* and a review of the Rhaetian genus *Eoconusphaera*. *Journal of Nannoplankton Research*, **39**(1): 77–87.

Demangel, I., Kovacs, Z., Richoz, S., Gardin, S., Krystyn, L., Baldermann, A. & Piller, W.E. 2020. Development of early calcareous nannoplankton in the Northern Calcareous Alps (Austria) in the Late Triassic. *Global and Planetary Change*, **193**: 103254.

Pérez Panera, J.P., Angelozzi, G.N., Riccardi, A.C., Damborenea, S.E. & Manceñido, M.O. 2021a. Triassic calcareous nannofossils from the Arroyo Malo Formation, Neuquén Basin, Argentina. First record in South America and implications on the early evolution of the group. 12º Congreso de la Asociación Paleontológica Argentina, Buenos Aires: 77.

Pérez Panera, J.P., Calvo Marcilese, L., Cuello, M.J. & Giampaoli, P. 2021b. First record of calcareous nannofossils from Chambará Formation, Pucará Group, Perú: A new biostratigraphic tool for regional correlation in the Late Triassic? 12º Congreso de la Asociación Paleontológica Argentina, Buenos Aires: 92.

Paleogene calcareous nannofossils from IODP Site U1553: Biostratigraphic, palaeoecological, and palaeoceanographic implications

Davide Persico
Dipartimento di Scienze chimiche della vita e della sostenibilità ambientale (SCVSA), Università degli Studi di Parma, Plesso di Scienze della Terra, Parco Area delle Scienze 157A, 43100 Parma, Italy; davide.persico@unipr.it

Isabella Raffi
Dipartimento di Ingegneria e Geologia (InGeo), Università degli Studi "G. d'Annunzio" di Chieti-Pescara, Campus Universitario, via dei Vestini 31, 66013 Chieti Scalo, Italy

Chiara Fioroni
Dipartimento di Scienze Chimiche e Geologiche, Università di Modena e Reggio Emilia, Via Campi, 103 41125 Modena, Italy

Giuliana Villa
Dipartimento di Scienze chimiche della vita e della sostenibilità ambientale (SCVSA), Università degli Studi di Parma, Plesso di Scienze della Terra, Parco Area delle Scienze 157A, 43100 Parma, Italy

In January 2020, International Ocean Discovery Program (IODP) Expedition 378 drilled in the South Pacific and recovered a continuously cored, multiple-holed Paleogene sedimentary section at Site U1553, located in the southern Campbell Plateau (Thomas et al., 2020). The aim was to replicate the sedimentary record of DSDP Site 277, drilled during Leg 29 in 1973, known as a reference palaeoceanographic section for the Paleogene (Kennett et al., 1975). From DSDP Site 277, two classic oxygen isotope records were generated that first defined the climatic evolution through the Eocene (Shackleton and Kennett, 1974; Savin, 1977). Improvements in coring technologies and better core–log integration have resulted in the development of triple-core stratigraphic splices that have resulted in a more complete succession than the single, partially spot-cored hole of Site 277. Research investigations on Site U1553 by high-resolution sampling are in progress, and allow the study, in unprecedented detail, all the biostratigraphic events preserved in this high-latitude sedimentary record (Fioroni et al., 2012; Hollis et al., 2015).

Here, we report on a preliminary study on calcareous nannofossil assemblages in an expanded Upper Eocene to Upper Oligocene sequence (with sedimentation rates of 19–22 m/Myr). The initial biostratigraphic results have confirmed the validity of the biozonation scheme proposed for the Southern Ocean (Fioroni et al., 2012) and suggest that further refinements of that biostratigraphic framework can be obtained from Site U1553, taking advantage of the rich and generally well preserved nannofossil assemblages observed in the studied interval.

The succession of recognised bioevents was compatible with the biozonation scheme proposed by Fioroni et al. (2012), placing the stratigraphic sequence studied in an interval between the Late Eocene and the Oligocene (from the *E. formosa* to *C. altus* zones). High-resolution biostratigraphic analyses of the lower part of the composite section showed differences in the stratigraphic distributions of *I. recurvus* and *R. clatrata* with respect to what has been observed at other Southern Ocean locations and reported in the biozonation of Fioroni et al. (2012).

A preliminary palaeoecological analysis was performed at low resolution on Hole U1553E. This suggested that different groups of taxa, considered representative of cool, temperate, eutrophic or oligotrophic conditions, may provide proxies for palaeotemperatures and nutrient concentrations, in line with previous studies at high southern-latitude sites (Villa et al., 2014). Further studies in progress at higher resolutions will certainly help in reconstructing changes in the South Pacific sea-surface temperature (SST), circulation and productivity associated with the greenhouse–icehouse transition (Eocene/Oligocene transition) and throughout the Early Oligocene interval. Moreover, the rich and well-preserved assemblages will provide new knowledge about the phylogeny of some species, such as *R. clatrata* and *R. oamaruensis*.

References

Fioroni, C., Villa, G., Persico, D., Wise, S.W. & Pea, L. 2012. Revised Middle Eocene–Upper Oligocene calcareous nannofossil biozonation for the Southern Ocean. *Revue de Micropaléontologie*, **55**: 53–70.

Hollis, C.J., Hines, B.R., Littler, K., Villasante-Marcos, V., Kulhanek, D.K., Strong, C.P., Zachos, J.C., Eggins, S.M., Northcote, L. & Phillips, A. 2015. The Paleocene–Eocene Thermal Maximum at DSDP Site 277, Campbell Plateau, southern Pacific Ocean. *Climate of the Past*, **11:** 1009–1025.

Kennett, J.P., Houtz, R.E., Andrews, P.B., Edwards, A.R., Gostin, V.A., Hajós, M., Hampton, M., Jenkins, D.G., Margolis, S.V., Ovenshine, A.T. & Perch-Nielsen, K. 1975. Introduction and explanatory note. *Initial Reports of the DSDP*, **29**.

Savin, S.M. 1977. The history of the Earth's surface temperature during the past 100 million years. *Annual Review of Earth and Planetary Sciences*, **5**: 319–355.

Shackleton, N.J. & Kennett, J.P. 1974. Paleotemperature history of the Cenozoic and the initiation of Antarctic glaciation: Oxygen and carbon isotope analyses in DSDP Sites 277, 279 and 281. *Initial Reports of the DSDP*, **29**: 743–755.

Thomas, D.J., Röhl, U., Childress, L.B. and the Expedition 378 Scientists 2020. Expedition 378 preliminary report: South Pacific Paleogene Climate. *International Ocean Discovery Program*.

Villa, G., Fioroni, C., Persico, D., Roberts, A.P. & Florindo, F. 2014. Middle Eocene to Late Oligocene Antarctic glaciation/deglaciation and Southern Ocean productivity. *Paleoceanography*, **29**: 223– 237.

New estimation of Late Paleocene calcareous nannoplankton fluxes from ODP Site 1209 (North Pacific)

Nicolas Pige, Guillaume Suan
Université Lyon 1, ENSL, UJM, CNRS, LGL-TPE, F-69622, Villeurbanne, France; nicolas.pige@univ-lyon1.fr
Pierre-Henri Blard
CRPG, Université de Lorraine, CNRS, UMR7358, Nancy, France
Emanuela Mattioli
Université Lyon 1, ENSL, UJM, CNRS, LGL-TPE, F-69622, Villeurbanne, France

The Early Paleogene was punctuated by several greenhouse-gas-driven hyperthermal events, the best known being the Paleocene–Eocene Thermal Maximum (PETM, 56 Ma). Planktonic organisms have been severely impacted by the environmental changes induced by abrupt events like these. Calcareous nannoplankton produce calcite shields using the dissolved carbon in oceanic surface waters, and these constitute a major component of deep-sea sediments. It is thus essential to produce highly resolved records of their production and burial across hyperthermals in order to better constrain their role in mitigating or amplifying ancient carbon-cycle perturbations.

Here, we present a quantitative assessment of the abundances of calcareous nannofossils and their fragments across a 1.2-Myr interval prior to the PETM at ODP Site 1209 (Pacific Ocean). The quantification of nannofossil fragment sizes and shapes allowed us to recalculate the nannofossil absolute abundances. We have developed a new age-model based on extraterrestrial ^{3}He to reconstruct fluxes of the exported calcite particles throughout the water-column. In parallel, dissolution was reconstructed thanks to planktonic foraminifera fragmentation and the sediment coarse fraction so as to disentangle the respective effects of production and dissolution on the nannofossil record.

Our main results challenge the widely accepted model previously developed for hyperthermal events, according to which $CaCO_3$ accumulation is mainly controlled by dissolution. Our results suggest that other parameters, such as temperature, water stratification and nutrient availability, exerted a major influence on carbonate production, export and accumulation for most of the Late Paleocene hyperthermal events.

Morphometric changes in two Late Cretaceous calcareous nannofossil lineages support diversification fueled by long-term cooling

Mohammad J. Razmjooei
Department of Geosciences and Natural Resource Management, University of Copenhagen, Øster Voldgade 10, DK-1350, Copenhagen C, Denmark & Department of Geological Sciences, Stockholm University, 106 91 Stockholm, Sweden; mj.razmjooei@gmail.com
Nicolas Thibault
Department of Geosciences and Natural Resource Management, University of Copenhagen, Øster Voldgade 10, DK-1350, Copenhagen C, Denmark

Morphometric changes in two calcareous nannofossil species—*Cribrosphaerella ehrenbergii* and *Microrhabdulus undosus*—were investigated in the Campanian–Maastrichtian. The results revealed a common episode of size increase at ~76 Ma, with a sudden shift in the size of *C. ehrenbergii* towards larger specimens and with the emergence of a larger, newly described species of *Microrhabdulus*—*sp. nov.* 1. An even larger species emerged at ~69 Ma in the *Microrhabdulus* lineage—*Microrhabdulus sp. nov.* 2. The timing of these size changes and origination events matches global changes in nannoplankton diversity and/or in the diversity of other planktonic organisms and cephalopods. A comparison with long-term global climate change supports these new biometric and evolutionary events representing an excellent illustration of the Late Cretaceous global rise in nannoplankton diversity and size, being associated with climatic cooling and/or climatic instability.

Mid-Pleistocene to Holocene calcareous nannofossil taxonomy and biochronology of the central Arctic Ocean

Mohammad J. Razmjooei, Matt O'Regan

Department of Geological Sciences, Stockholm University, Stockholm SE-106 91, Sweden; mj.razmjooei@gmail.com

Jorijntje Henderiks

Department of Earth Sciences, Uppsala University, Uppsala SE-752 36, Sweden

Karl-Heinz Baumann

Geosciences, University of Bremen, PO Box 330440, 28334 Bremen, Germany

A half-century of research (since the 1970s) has indicated that accurate dating of the sediments in the Arctic Ocean is not straightforward due to some puzzling magnetic polarity patterns, the lack or scarcity of microfossils, and the discontinuous oxygen isotope records from Arctic marine sediments. Recently, two important biohorizons of calcareous nannofossils, including the first occurrence of *Emiliania huxleyi* (291 ka: Raffi et al., 2006) and the last occurrence of *Pseudoemiliania lacunosa* (436 ka: Raffi et al., 1977) were reported for the first time from the central Arctic (LRG12-3PC) (O'Regan et al., 2020). In order to study the taxonomic composition and abundance of the calcareous nannofossil taxa and expand on the results provided by O'Regan et al. (2020), a high-resolution stratigraphic analysis of Upper Quaternary sediments was undertaken on three cores from the Lomonosov Ridge (LRG12-7PC, LRG12-9PC and AO16-5-PC1) and one from the Makarov Basin (AO16-8GC) in the central part of the Arctic Ocean. Although our studies confirm the presence of the two bioevents across the central Arctic, the extremely low abundances and variable preservation can make it very difficult to confidently resolve their stratigraphic positions. Through detailed sampling and cross-verification, using transmitting light and scanning electron microscope imaging, a new stratigraphic framework that supports the key bioevents is emerging. This may signifcantly change the geochronological framework for central Arctic Ocean sediments, with the implication that what were previously identified as substages (interstadials) in Marine Isotope Stage 5 were actually separate interglacials. The presence and absence patterns of the nannofossil markers in the studied cores allowed the standard NN19, NN20 and NN21 nannofossil zones of Martini (1971) to be applied, thus placing the upper 2–3 m of the cores in the Mid-Pleistocene to Holocene.

References

Martini, E. 1971. Standard Tertiary and Quaternary calcareous nannoplankton zonation. *In*: A. Farinacci (Ed.). *Proceedings of the II Planktonic Conference, Roma, 1970. Edizioni Tecnoscienza, Roma*: 739–785.

O'Regan, M., Backman, J., Fornaciari, E., Jakobsson, M. & West, G. 2020. Calcareous nannofossils anchor chronologies for Arctic Ocean sediments back to 500 ka. *Geology*, **48**(11): 1115–1119.

Raffi, I., Backman, J., Fornaciari, E., Pälike, H., Rio, D., Lourens, L. & Hilgen, F. 2006. A review of calcareous nannofossil astrobiochronology encompassing the past 25 million years. *Quaternary Science Reviews*, **25**(23–24): 3113–3137.

Perturbing coccolithophores: The past and future of Earth's stabilisers

Rosalind E. M. Rickaby
Department of Earth Sciences, University of Oxford, South Parks Road, Oxford OX1 3AN, UK; rosalind.rickaby@earth.ox.ac.uk

Coccolithophores are single-celled, photosynthesising algae that precipitate a multitude of intricate calcium carbonate liths inside their cells before expelling them to form external spherical armour. Although microscopic in stature, coccolithophores have exerted a gigantic influence on Earth's carbon cycle since their emergence in the Triassic. Massive accumulations of calcium carbonate coccoliths (an estimated flux of ~6 x 10^{25} liths/year) contribute to the export of organic matter from the mixed layer, and ultimately form sediments on the deep seafloor, a dominant sink of carbon from the atmosphere over geological timescales, playing a role in Earth's thermostat and acting as a buffer for seawater chemistry. Through this carbon sink, the coccolithophores have exerted an influence on the ocean and atmosphere, but similarly, this changing carbon cycle has driven genetic and physiological innovation and adaptation within the coccolithophores. In this talk, I will explore, using novel bio(geo)chemical tools, how coccolithophores and the environment are linked in an inescapable feedback in the geological past, and how looking to the past may help to predict their future destiny in a rising-carbon world.

Calcareous nannoplankton from the uppermost Triassic of the Southern Alps, Slovenia

Matic Rifl, Katarína Holcová
Institute of Geology and Palaeontology, Albertov 6, Prague 2, 128 43, Czech Republic; rifl.matic@gmail.com

In Slovenia, Upper Triassic limestone outcrops represent one of the most widespread lithologies. Most of these are currently exposed in the mountain faces of the Southern Alps and the steep hills of the External Dinarides. The Upper Triassic carbonate successions were deposited on the passive western margin of Pangaea facing the Tethys Ocean. These sediments were tectonically uplifted through convergence and subduction processes, now allowing us to get an insight into the formerly predominantly marine environments of the region. Norian and Rhaetian beds in Slovenia lay conformably on Carnian rocks and show a continuous upwards transition into the different settings of the Early Jurassic. The aim of this research was a preliminary study of the uppermost Triassic calcareous nannoplankton.

During the Late Triassic, the formation of the Central Atlantic Magmatic Province propagated changes governed by relatively short-term pH oscillations, which reshuffled the balance of the global oceanic biogeochemical cycles. Despite the number of scientific publications focusing on Late Triassic nannofossils, little is known about the nannoplankton assemblages during their first mass extinction close to the Triassic/Jurassic boundary. The Upper Norian to Rhaetian Slatnik Formation, located in the Kobla Nappe Complex, is seen as a continuous basinal development from Late Triassic to Early Jurassic facies. Samples were taken from the uppermost Triassic part of the Povdnar section, which is composed of thinly bedded to platy marlstones and marly limestones, which have been interpreted as hemipelagic or partly distal turbidites. The extraction of coccoliths from these carbonate rocks is challenging due to the diagenetic overprint. The samples were crushed in a mortar and dry-sieved over a 0.02-mm sieve. The crushed sediment was frozen and then boiled in water with an added dispersion agent. Ultimately, the calcareous nannoplankton were studied on smear slides over 200 fields of view. Using this approach, we were able to confirm that calcareous nannoplankton occurred more frequently in the marlstone than in the marly limestones. The assemblages identified were mostly represented by recrystallised nannoliths belonging to *Prinsiosphaera triassica* and, more rarely, *Eoconusphaera zlambachensis*. Future research will focus on further steps in wet sieving and sample enrichment. We intend to sieve the sample using a 63-μm mesh and dilute the suspension to a uniform volume. For the sample enrichment, we have assembled a multistage apparatus that will enable the repeated wet vacuum-powered acoustic microfiltration of particles smaller than 1 μm, which end up in a collection vessel. The calcareous nannoplankton will be further studied using a scanning electron microscope. Finally, the nannofossil diversity, abundance and facies dependence will be compared to those from other upper Norian–Rhaetian sections in Slovenia and the Western Carpathians in Slovakia.

Role of coccolithophore floristics on alkenone-derived temperatures in the subantarctic Southern Ocean

Andrés S. Rigual-Hernández, Francisco J. Sierro, José Abel Flores
Área de Paleontología, Departamento de Geología, Universidad de Salamanca, 37008 Salamanca, Spain; arigual@usal.es

Tom W. Trull
CSIRO Oceans and Atmosphere, Hobart, Tasmania 7001, Australia & Institute for Marine and Antarctic Studies, University of Tasmania, Private Bag 129, Hobart, Tasmania 7001, Australia & Antarctic Climate and Ecosystems Cooperative Research Centre and Australian Antarctic Program Partnership, University of Tasmania, Hobart, Tasmania 7001, Australia

Teresa Rodrigues
Portuguese Institute for Sea and Atmosphere (IPMA), Divisão de Geologia Marinha, Rua Alfredo Magalhães Ramalho 6, Lisboa, Portugal & CCMAR, Centro de Ciências do Mar, Universidade do Algarve, Campus de Gambelas, 8005-139 Faro, Portugal

Belén Martrat
Department of Environmental Chemistry, IDAEA-CSIC, 08034 Barcelona, Spain

Elizabeth Sikes
Marine and Coastal Sciences, Rutgers University, New Brunswick, NJ, USA

Scott D. Nodder
National Institute of Water and Atmospheric Research, Wellington 6021, New Zealand

Ruth S. Eriksen
CSIRO Oceans and Atmosphere, Hobart, Tasmania 7001, Australia & Institute for Marine and Antarctic Studies, University of Tasmania, Private Bag 129, Hobart, Tasmania 7001, Australia

Diana Davies
CSIRO Oceans and Atmosphere, Hobart, Tasmania 7001, Australia & Antarctic Climate and Ecosystems Cooperative Research Centre and Australian Antarctic Program Partnership, University of Tasmania, Hobart, Tasmania 7001, Australia

Natalia Bravo
Department of Environmental Chemistry, IDAEA-CSIC, 08034 Barcelona, Spain

José M. Sánchez-Santos
Departamento de Estadística, Universidad de Salamanca, 37008 Salamanca, Spain

Fátima Abrantes
Portuguese Institute for Sea and Atmosphere (IPMA), Divisão de Geologia Marinha, Rua Alfredo Magalhães Ramalho 6, Lisboa, Portugal & CCMAR, Centro de Ciências do Mar, Universidade do Algarve, Campus de Gambelas, 8005-139 Faro, Portugal

Alkenones are a class of unsaturated long-chain methyl and ethyl ketones with a variable degree of unsaturation that represent one of the most robust proxies for the reconstruction of past sea-surface temperatures (SSTs). Globally, the alkenone unsaturation index has been shown to change linearly with temperature. However, discrepancies between measured and alkenone-derived temperatures have been documented in subpolar regions of both hemispheres. In order to assess the influence of biotic and abiotic factors in alkenone production and preservation in the subantarctic Southern Ocean, alkenone fluxes were measured in three vertically moored sediment traps (at 1000, 2000 and 3800 m depth) deployed during one year (from August 2011 to July 2012) at the Southern Ocean Time Series observatory (SOTS) at 46º56'S, 142º15'E.

Overall, alkenone-based reconstructions of water temperatures generally mirror the seasonal variations of temperature at the surface. However, some important discrepancies (~10ºC deviations) were identified at the onset of the record (in August and September, i.e. austral winter) and attributed to either low light stress or selective degradation of the more unsaturated alkenones due to prolonged residence time in the water-column. Moreover, the alkenone imprint in the deepest sediment trap suggested a systematic positive offset of about 3ºC with respect the 1000 and 2000-m traps, which was attributed to pronounced selective degradation of the more unsaturated alkenones in the lower half of the water-

column and/or input of allochthonous alkenones transported by a deep eastern boundary current. Notably, we identified a strong and significant correlation between the seasonal variations of *Emiliania huxleyi* ecotypes and temperature deviations between the alkenone-derived temperatures and in-situ SSTs. Our results suggest that *E. huxleyi* var. *aurorae*, endemic to the Southern Ocean, might produce a higher proportion of C37:3 relative to C37:2 compared to its warm-water counterparts. Thus, it seems likely that the shift in the dominance of *E. huxleyi* south of the Subantarctic Front could be at least partially responsible for the less accurate alkenone-based SST reconstructions in the Southern Ocean using global calibrations.

Environmental factors influencing calcareous nannofossil distribution over the past 96,000 years from the Panama Basin, eastern equatorial Pacific

John Sarao
Texas A&M University, College Station, TX, USA; john.sarao@tamu.edu
Denise K. Kulhanek
Christian-Albrechts-University of Kiel, Kiel, Germany

Fully and accurately reconstructing changes in productivity and carbon export is critical to determining the efficiency of the biological pump and its role in the global carbon cycle through time, particularly in modern CO_2 source regions like the eastern equatorial Pacific (EEP). Sediment from the Panama Basin (Site MV1014-02-17JC) was used to make smear-slides by the drop method for the identification of calcareous nannofossils through light-microscopy. This study presents a new, high-resolution record of calcareous nannofossil assemblage changes, together with previously published diatom assemblage data, and geochemical proxy data, including alkenone-derived sea-surface temperatures (SSTs), ^{230}Th-derived ^{232}Th wind-blown dust flux, ^{230}Th-derived xBa, authigenic uranium, ^{234}U/^{238}U and opal flux, from the Panama Basin to assess environmental controls on the phytoplankton community.

The assemblages were well preserved and abundant throughout the 96-kyr record derived from this region. The assemblages were dominated by *Gephyrocapsa oceanica* and *Florisphaera profunda*, with an additional 14 species being present throughout the studied interval. Principle coordinate analysis (PCO) was used to assess variations in species abundances among the samples. Each PCO was used as the response variable in a multiple linear regression, with all environmental factors as predictor variables in order to determine which environmental factors best represented the changes observed in the floral composition. The phytoplankton community structure was driven by changing patterns of nutrient availability (most notably the Si:Fe ratio), which, in turn, was caused by variability in the position of the Intertropical Convergence Zone (ITCZ) and associated changes in biogeochemical cycling and circulation in the Southern Ocean. Silica-rich waters brought to the surface from the equatorial undercurrent favoured a diatom-dominated community, whereas, when wind-blown dust brought an excess of iron in the absence of bioavailable silica, the calcareous nannoplankton thrived. Ultimately, this study aims to disentangle the effects of nutrient delivery regimes along an eastern boundary upwelling system and their controls on the structure of the phytoplankton community.

The effect of temperature on the photosynthetic underpinnings of coccolithophore calcification

Krisztina Sárközi, Rosalind Rickaby
Department of Earth Sciences, University of Oxford, Oxford OX1 3AN, UK; krisztina.sarkozi@earth.ox.ac.uk

Coccolithophores, like many phytoplankton species, evolved distinct strategies to fine-tune their metabolism to the environment, likely by involving the differential allocation of resources between photosynthesis, growth and calcification via efficiencies and trade-offs between each pathway, and yet there is little mechanistic understanding of how energy and carbon flow between photosynthesis and calcification in coccolithophores, and how this dynamic coupling is affected by resource limitation and environmental stress.

We aim to determine how calcification rate is affected by different strategies of resource allocation under control conditions and environmental stress by measuring calcification and photosynthetic rates from alkalinity drift, PIC/POC and O_2-electrode, complemented with SEM observations of size and morphology.

Here, we report some preliminary results on how geographically different isolates of the cosmopolitan bloom-forming *Gephyrocapsa* (formerly *Emiliania*) *huxleyi* morphotypes, productivity and calcification change their physiology in response to temperature and explore the implications for biogeochemical cycles.

Late Holocene ecological trends in the Levant Basin from fossil phytoplankton assemblages

Jakob Schneider, Denise K. Kulhanek
Institute of Geosciences, University of Kiel, Ludewig-Meyn-Straße 10-14, 24118 Kiel, Germany; stu226419@mail.uni-kiel.de
Or M. Bialik
Dr. Moses Strauss Department of Marine Geosciences, The Leon H. Charney School of Marine Sciences, University of Haifa, Carmel 31905, Israel
Guy Sisma-Ventura
Israel Oceanographic and Limnological Research (IOLR), Haifa 3108000, Israel

The Levant Basin in the eastern Mediterranean Sea is largely influenced by discharge from the Nile River, controlling the input of freshwater, sedimentary particles and nutrients. Since the 1960s, construction of the Aswan High Dam has resulted in a significant alteration in the aforementioned parameters in the Levant Basin and eastern Mediterranean, in general. Coccolithophores are suitable organisms for studying ecological fluctuations, as they are highly abundant in the plankton and well preserved in the sediment. Their general significance is underlined by their role in primary production and carbon fixation via calcification.

To further our understanding of ecosystem variability in this region, we looked at nannofossil assemblages from three sites covering the past ~1000 years. The site locations spanned a transect across the continental shelf (Site HS120), rise (Site HO4) and deep basin (Site HO6), and were collected during a cruise of the R/V *Bat-Galim* with a box-corer (Ocean-Model BX-650). Each core was sectioned into half-centimetre slices immediately after collection and frozen. We prepared the samples using the drop technique to allow for the calculation of absolute nannofossil abundances. Census counts for each sample were conducted using cross-polarised and plane transmitted light using a Leica CTR6000 microscope to look at species diversity and abundance. Our initial results show that the nannofossil abundance was significantly higher in the continental rise and deep basin sites relative to the continental shelf site. The coccolithophore assemblages were dominated by the cosmopolitan taxon *Emiliania huxleyi*. Less abundant taxa included the genera *Gephyrocapsa*, *Syracosphaera* and *Helicosphaera*, along with species such as *Coccolithus pelagicus*, *Calcidiscus leptoporus*, *Florisphaera profunda*, *Calciosolenia brasiliensis*, *Rhabdosphaera clavigera* and *Braarudosphaera bigelowii*. Diatoms and calcareous dinoflagellates (*Thoracosphaera* sp.) were also present in varying abundances. This study will elucidate changes in phytoplankton communities in recent history—a time period during which changes in human land usage likely had an influence on the delivery of nutrients into the Mediterranean Sea.

Calcareous nannofossil assemblages in sediment cores from the northern Red Sea: First results and palaeoecological reconstructions

Bhakti Shah
Leibniz Centre for Tropical Marine Research (ZMT), 28359 Bremen, Germany & Centre for Marine Environmental Sciences (MARUM), 28359 Bremen, Germany & University of Bremen, Department of Geosciences, 28359 Bremen, Germany; bhakti.shah@leibniz-zmt.de

Karl-Heinz Baumann
University of Bremen, Department of Geosciences, 28359 Bremen, Germany

Alexander Petrovic
ANPERC, King Abdullah University of Science and Technology (KAUST), ANPERC, 23955 Thuwal, Saudi Arabia & RSRC, King Abdullah University of Science and Technology (KAUST), ANPERC, 23955 Thuwal, Saudi Arabia

Hildegard Westphal
Leibniz Centre for Tropical Marine Research (ZMT), 28359 Bremen, Germany & University of Bremen, Department of Geosciences, 28359 Bremen, Germany & RSRC, King Abdullah University of Science and Technology (KAUST), ANPERC, 23955 Thuwal, Saudi Arabia

The Red Sea is a desert-surrounded ocean basin with a shallow and narrow seaway to the Indian Ocean. Warm and normal saline waters enter the Red Sea from the Gulf of Aden, move northwards along the longitudinal axis of the basin, and become cooler, saltier and oligotrophic. However, the environment suffered extreme oceanographic changes during the last glacial–interglacial cycle. The water exchange with the Gulf of Aden was even more restricted during the last glacial, such that the salinity of the Red Sea waters increased considerably, with dramatic effects on its biological interior.

In comparison to other plankton, little is known about the calcareous nannofossils of the Red Sea. Therefore, a qualitative and quantitative study of the calcareous nannofossil assemblages was performed on two sediment cores obtained close to the Al Wajh Platform in the northern Red Sea near the coast of Saudi Arabia. The two 300-cm long cores were sampled at 5–15-cm intervals and prepared for SEM investigations using a combined dilution/filtering technique. The total calcareous nannofossil numbers range from >10,000 × 10^6 coccoliths/g in the Holocene (above the two sapropels RS1a and RS1b) to numbers of around 4000 × 10^6 coccoliths/g in the Late Glacial. Abundance variations occurred across the diverse communities, with up to 35 species and species groups being identified. This suggests changes in ecological conditions in the Red Sea, with the higher primary productivity estimates from the Glacial compared to the Holocene being derived from abundances of the deep-living *Florisphaera profunda*. Furthermore, significantly increased proportions of holococcolithophores in the glacial section indicated good preservation in this phase, while individual glacial samples were also influenced by carbonate overgrowth. The observed variations will be discussed in detail in our poster.

Improving characterisation of the tight Lower Cretaceous marly chalk reservoir, central North Sea: A nannofossil biostratigraphic, sequence stratigraphic and sedimentological approach

Emma Sheldon
Department of Geo-energy and Storage, Geological Survey of Denmark & Greenland (GEUS), Øster Voldgade 10, DK-1350, Copenhagen K, Denmark; es@geus.dk

Jon Ineson
Department of Geophysics and Sedimentary Basins, Geological Survey of Denmark & Greenland (GEUS), Øster Voldgade 10, DK-1350, Copenhagen K, Denmark

Kresten Anderskouv
Department of Geosciences and Natural Resource Management, Geology Section, University of Copenhagen, Øster Voldgade 10, DK-1350, Copenhagen K, Denmark

Lower Cretaceous reservoir-grade chalks and marly chalks have been a secondary target for hydrocarbon exploration and production in Denmark for decades. However, the urgent focus on climate change and the recent end to hydrocarbon exploration in Denmark has shifted the industry's attention towards field development.

Development of the Valdemar–Boje–Adda area in the Danish sector of the North Sea has required an up-to-date understanding of the architecture of the low-permeability Lower Cretaceous hydrocarbon reservoir. We have carried out an extensive nannofossil-biostratigraphic, well-log and sedimentological investigation on selected wells from the area. Industrial biostratigraphic interpretation usually relies on confidential, field-specific, oil-company/consultancy-company zonation schemes. However, we have applied the published boreal nannofossil zonation schemes—the BC zones of Bown et al. (1998) and the LK zones of Jeremiah (2001)—to the Upper Hauterivian to Barremian Tuxen Formation (BC7–BC16, LK26–LK15) and the Upper Barremian to Lower Aptian Sola Formation (BC16–BC21, LK15–LK12), which, coupled with new log interpretations and sedimentological logging, have provided a new stratigraphic model for the area.

The improved stratigraphic framework has increased our understanding of the structural history and sedimentary development of the area, and has been implemented in reappraisal of the Adda Field. Current studies are focused on extending this framework to assist further development of the Lower Cretaceous chalks in the Tyra Field to the south-east.

References

Bown, P., Rutledge, D.C., Crux, J.A. & Gallagher, L.T. 1998. Lower Cretaceous. *In*: P.R. Bown (Ed.). *Calcareous nannofossil biostratigraphy*. British Micropalaeontological Society Series. Chapman & Hall/Kluwer Academic: 86–131.

Jeremiah, J. 2001. A Lower Cretaceous nannofossil zonation for the North Sea Basin. *Journal of Micropalaeontology*, **20**: 45–80.

Poorly recognised diversity in PIC:POC ratios underpins the role of coccolithophores in the marine carbon cycle

Rosie M. Sheward, Jens O. Herrle
Institute for Geosciences, Goethe-University Frankfurt, Frankfurt am Main, Germany; sheward@em.uni-frankfurt.de
Alex J. Poulton
The Lyell Centre for Earth and Marine Sciences, Heriot-Watt University, Edinburgh, Scotland

Throughout their evolutionary history, coccolithophores have shown a spectacular array of diversity in coccolith morphology, coccosphere architectures and cell size that leads to specific cellular particulate inorganic carbon (PIC, calcite) and particulate organic carbon (POC, biomass) characteristics for each species. As biogenic calcite production is a source of CO_2 and biomass production is a sink for CO_2, there has been extensive investigation into the physiological and environmental influences on the PIC:POC ratio and the development of its use as a major biogeochemical trait for this plankton group. However, because much of our knowledge of coccolithophore PIC:POC ratios stems from laboratory experiments on a limited selection of species in culture (i.e. *Emiliania huxleyi*) and from bulk analysis of field population samples that integrate the PIC and POC of all species present in the assemblage, the diversity of PIC:POC ratios across coccolithophore species remains poorly quantified. This limits our ability to identify which species, taxonomic or functional groups contribute more (or less) significantly to community calcite and biomass production, and therefore the biogeochemical and ecological consequences of species extinctions, range shifts or changes in productivity due to climate or biotic pressures.

Here, we present recent insights into the PIC and POC diversity of extant coccolithophores and fossil calcareous nannoplankton by quantifying the morphology of thousands of individual coccospheres from laboratory cultures, filtered surface seawater samples and well-preserved marine sediments. Across individual cells, the PIC:POC ratios showed a very broad range, from ~20:1 (e.g. heavily calcified cells of *Braarudosphaera*) to ~1:20 (e.g. lightly calcified cells of *Kilwalithus*), although the majority of individual cells typically lay between a PIC:POC ratio of 2:1 and 1:2. Taxa that may appear to be 'heavily calcified' (e.g. *Umbilicosphaera*) can have a lower cellular PIC:POC ratio than expected if they are associated with larger cells (and therefore more POC) and vice versa. The intra-species range in PIC:POC ratios can also be substantial because this is a function of the variability in coccolith size and morphology, the number of coccoliths per cell, and cell size. All these parameters have been shown to be influenced at the cellular level by environmental factors and at the population level by the mixing of ecotypes or morphotypes with different morphological characteristics and physiological states. Overlapping PIC:POC ratio ranges for many species indicate the potential for some degree of 'functional redundancy' in coccolithophore communities, providing that the ecophysiology of replacement species does not differ substantially. The remarkable diversity in PIC:POC ratios across coccolithophores past and present strongly suggests that a 'one-size-fits-all' approach to coccolithophore PIC:POC ratios is not sufficient to capture the biogeochemical and ecological consequences of changes in community structure, species productivity or biogeography.

Correlation of the calcareous nannofossil biostratigraphies of the Cenomanian–Turonian Poigny core and Quero section

Michela Simonato
Dipartimento di Geoscienze, Università degli Studi di Padova, Italy; michela.simonato.1@phd.unipd.it
Silvia Gardin
Center for Research on Palaeobiodiversity and Palaeoenvironments, Sorbonne University, Place Jussieu 4, 75252 Paris, France
Valeria Luciani
Dipartimento di Fisica e Scienze della Terra, Università degli Studi di Ferrara, Italy
Luca Giusberti, Eliana Fornaciari
Dipartimento di Geoscienze, Università degli Studi di Padova, Italy

The Late Cenomanian–Turonian interval was characterised by global changes in the carbon cycle, as identified by peaks in stable carbon isotope excursions, associated with climatic variations. Specifically, the Late Cenomanian records a warming trend, culminating with Oceanic Anoxic Event 2 (OAE2). However, during the Turonian, frequent cooling phases occurred that ended with a Late Turonian Cool Phase. The palaeoenvironmental variations related to climate change influenced the primary producers (e.g. calcareous nannoplankton assemblages), leading to biotic turnover. A sound biostratigraphic framework is therefore crucial for understanding the tempo and mode of these biotic changes and the accurate timing of these climatic variations. Calcareous nannofossil assemblages are a useful tool for such purposes, although some species exhibited diachroneity and/or taxonomic ambiguity (e.g. *Eiffellithus eximius*) during the Cenomanian–Turonian interval.

We present new data on the calcareous nannofossil biostratigraphy of the Quero section (Belluno Basin, north-eastern Italy) and Poigny core (Paris Basin, France) with the purpose of comparing a southern Boreal core (Poigny) with a north-western Tethyan section (Quero) and assessing the synchroneity/diachroneity of the calcareous nannofossil biohorizons observed. We have highlight several useful biohorizons and peculiar evolutionary lineages, such as the *E. turriseiffelii* to *E. eximius* evolutionary trend. In addition, we compared the calcareous nannofossil data with those of planktonic foraminifera and stable isotopes (Le Callonnec et al., 2021) in order to obtain more accurate information regarding how the climatic changes influenced the biotic variations in abundance of selected species, the extinctions and evolutionary radiations. Finally, we correlate our data with those of other reference sections.

References

Le Callonnec, L., Briard, J., Boulila, S., Galbrun, B. 2021. Late Cenomanian–Turonian isotopic stratigraphy in the chalk of the Paris Basin (France): A reference section between the Tethyan and Boreal realms. *BSGF–Earth Sciences Bulletin*, **192**(1): 1–14.

Coccolithophore assemblages from the central Adriatic Sea

Sanda Skejić, Jasna Arapov, Ana Bakrač, Mia Bužančić, Živana Ninčević Gladan

Institute of Oceanography and Fisheries, Šetalište I. Meštrovića 63, 21000 Split, Croatia; sanda@izor.hr

The coccolithophore community was studied in monthly plankton samples from the open waters of the central Adriatic Sea. The samples were collected along vertical profiles up to 100 m deep in 2018. The average contribution of coccolithophores to the phytoplankton community was 26%. Higher proportions (more than 50%) were recorded in the surface layers in August, and contributions reached up to 71% in November and December. The average abundance of coccolithophores throughout the study period was 8.9 x 10^3 cells l^{-1}, with maximum values of up to 2.6 x 10^4 cells l^{-1} in May, when the highest number of coccolithophore morphotypes was also recorded. The same month was characterised by the highest HOLP index, indicating the highest number of holococcolith forms.

As for the vertical distribution, the abundance of coccolithophores was highest at 10 m depth and decreased towards 100 m depth. Spearman's rank correlation showed a positive correlation between Chl-a and diatoms ($R = 0.522$, $p < 0.005$). *Emiliania huxleyi* dominated the coccolithophore assemblage in the Adriatic Sea and was also predominant at all investigated depths, especially from November to March, which is consistent with previous studies. *Emiliania huxleyi* accounted for up to 72% of the coccolithophore community during this period. Although the abundance of *E. huxleyi* was lower in summer, as was its proportion of the community in the surface layers (only 3%), the proportion of *E. huxleyi* increased to as much as 70% in the deeper layers below 50 m depth. In this study, *E. huxleyi* morphotype A dominated, but several cells of *E. huxleyi* type O were also detected. The O morphotype was observed for the first time in the Adriatic Sea.

Did the 33.4 Ma Eastern Rhodope supereruptions contribute to Early Oligocene cooling? Calcareous nannofossil data from the St. Sozon section, Limnos

Kristalina Stoykova, Peter Marchev, Raya Raycheva, Rositsa Ivanova, Georgi Granchovski

Geological Institute, Bulgarian Academy of Sciences, 24 Acad. G. Bonchev Str., BG-1113 Sofia, Bulgaria; stoykova@geology.bas.bg, pmarchev@geology.bas.bg, raya@geology.bas.bg, rossiv@geology.bas.bg, georgi2801@geology.bas.bg

The purpose of the present study was to estimate the impacts of two closely spaced Eastern Rhodope Duzhdovnitsa supereruptions around the Eocene/Oligocene boundary (EOB) on the marine plankton and climate conditions. To accomplish these objectives, we studied calcareous nannoplankton assemblages from the St. Sozon section (Fisini–Sardes unit) on Limnos Island, Greece. The section is part of a continuous, >1000-m-thick sedimentary succession (deep-water turbidites) encompassing the EOB, including two tuff beds. The latter have been precisely dated at 33.38±0.37 Ma and 33.31±0.61 Ma, thus providing numerical age constraints for our detailed nannofossil study. The exposures were located at St. Sozon Cape (39º48”24.1’N, 25º21”48.5’E), currently situated ~200 km south of the Borovitsa Supervolcano, which is the supposed source of the eruption. The two tuff beds—lower (6.5–7-m thick) and upper (~3.5-m thick)—were separated by 7 m of sediments. The U–Pb zircon ages for the lower bed (33.38±0.37 Ma and 33.31±0.61 Ma) were slightly younger than the EOB (33.9 Ma), but very close to the globally recognised Oligocene Oi-1 cooling event.

The total number of nannofossil samples examined was 78. The average sampling resolution was ~5 m, increasing to 0.2–0.3 m around the tuff layers. For each sample, nannofossils were taxonomically and quantitatively estimated by logging at least 300 fields of view on the smear slide. Our biostratigraphic results show that the CNE20, CNE21, CNO1 and CNO2 nannofossil zones of Agnini et al. (2014) were present. The EOB was identified by the base common occurrence of *Clausicoccus subdistichus*, at 4 m below the base of the first tuff bed.

The quantitative analysis of the calcareous nannofossils showed clear differences in the absolute abundances from below and above the tuff layers. Prior to the eruptions, the nannofossil assemblages were dominated by warm-water oligotrophic taxa, such as the rosette-like discoasters (*D. saipanensis* and *D. barbadiensis*), reticulofenestrids, *Cribrocentrum* and *Helicosphaera*. After the eruptions, due to the temporary suspension of photosynthesis, the assemblages sharply decreased until their complete extinction in the tuff layers. The Early Oligocene nannofloras were significantly altered, with an increasing proportion of cold-water and meso-eutrophic taxa (*Coccolithus*) and a flux of the representatives of *Clausicoccus*. We conclude that the volcanic products—pyroclastic flows, ash and gases—of the two consecutive eruptions covered large areas of Eastern, Central and Southern Europe, including present-day Limnos Island to the south, and caused a substantial decrease in nannoplankton production and a lowering of the temperature.

Acknowledgements: This work was carried out within the framework of Project H24/3, funded by the National Science Fund of Bulgaria.

The Paleocene–Eocene Thermal Maximum Riben section revisited (northern Bulgaria, south-eastern Europe): New nannofossil and foraminiferal isotope data

Kristalina Stoykova
Geological Institute Bulgarian Academy of Sciences, 24 Acad. G. Bonchev Str., 1113 Sofia, Bulgaria; stoykova@geology.bas.bg

Torsten Vennemann
University of Lausanne, Stable Isotope Laboratory, Geopolis 4634, CH-1015 Dorigny, Switzerland

Marin Ivanov
Sofia University "St. Kl. Ohridski", Faculty of Geology and Geography, 15 Tsar Osvoboditel Blvd., 1000 Sofia, Bulgaria

Georgi Granchovski
Geological Institute Bulgarian Academy of Sciences, 24 Acad. G. Bonchev Str., 1113 Sofia, Bulgaria

The occurrence of the Paleocene–Eocene Thermal Maximum (PETM) event in Bulgaria was discovered in 2005, based on calcareous nannofossil and bulk-rock isotope data from three sections in northern Bulgaria—Kladorub, Riben and Bozhuritsa (Stoykova & Ivanov, 2005). Since then, studies have continued in order to investigate the composition of the nannofossil assemblages and the biotic response of the nannoplankton communities to the extreme global warming during the PETM, as well as to document essential changes in the $\delta^{13}C$ and $\delta^{18}O$ compositions in the Paleocene/Eocene boundary interval.

Here, we present the results from the revisited Riben section (central northern Bulgaria), where two parallel, slightly overlapping new trenches have been excavated on the right-hand side of the abandoned quarry. High-resolution sampling, every ~25 cm, was performed through the entire NP9 zone and PETM interval. The total number of samples analysed for calcareous nannofossils and isotope geochemistry ($\delta^{13}C$ and $\delta^{18}O$) was 35. The $\delta^{13}C$ and $\delta^{18}O$ measurements were performed on isolated (*Cibicidoides*) foraminifera tests. The preliminary nannofossil biostratigraphy showed the relative completeness of the section across the Paleocene/Eocene boundary. The sedimentology suggested that deposition likely took place in a middle-shelf setting.

The pre-PETM nannofossil assemblages were rich and diversified, comprising, among others, abundant *Coccolithus* and *Toweius* species. These two genera dominated over *Discoaster* representatives. The onset of the warming was expressed geochemically by a sharp negative $\delta^{13}C$ excursion (CIE) from -0.05 to -4.90‰, and by a similar negative $\delta^{18}O$ excursion, but on a smaller scale (from -4.11 to -5.72‰, Sample R23). Moreover, it was marked by a decrease in the carbonate content of the sediments and the deposition of a clayey interval—a light beige to rusty-brown claystone, ~45-cm thick. Above the base of the CIE, a specific warm-water nannofossil association was identified, represented by abundant discoasters (*D. salisburgensis*, *D. lenticularis*, *D. multiradiatus*, *D. araneus*) and less-common coccoliths (*Coccolithus pelagicus*, *Toweius tovae*, *T. serotinus*). Other stratigraphically important species—*Rhomboaster bramlettei* and *R. calcitrapa*—exhibited rare occurrences in the core of the PETM interval.

Above the PETM, a normal biostratigraphic succession of NP10, NP11 and NP12 was documented. Additional samples from the upper portion of the PETM were taken, and further investigations are underway. Acknowledgements: This work was carried out within the framework of the National Science Program 'Environmental Protection and Reduction of Risks of Adverse Events and Natural Disasters' (Agreement No. D01-279/03-12-2021).

References

Stoykova, K. & Ivanov, M. 2005. First data on the presence of the Paleocene–Eocene Thermal Maximum in Bulgaria. *Comptes Rendus de l'Académie Bulgare des Sciences*, **58**(3): 297–302.

Campanian–Maastrichtian boundary interval at Beloptichene (Kula tectonic unit, north-western Bulgaria): New nannofossil data

Georgi Granchovski, Kristalina Stoykova

Geological Institute, Bulgarian Academy of Sciences, Acad. G. Bonchev Str., Bl. 24, 1113 Sofia, Bulgaria; georgi2801@geology.bas.bg, stoykova@geology.bas.bg

Based on detailed calcareous nannofossil biostratigraphy and stable isotope analyses, Stoykova et al. (2020) recently recognised the presence of the Campanian–Maastrichtian Boundary Event (CMBE), and possibly the Late Campanian and Mid-Maastrichtian Events, for the first time in Bulgaria, at Kladorub (north-western Bulgaria). This has sparked interest in the search for other complete sections of the Campanian–Maastrichtian boundary interval that may record Late Cretaceous palaeoclimatic events in the country, which is still a somewhat understudied region in this regard. In lieu of that, the calcareous nannofloras from the Upper Cretaceous–Paleogene sedimentary succession at Beloptichene (Kula tectonic unit, north-western Bulgaria) have been re-examined in order to assess their preservation and the completeness of the section.

At Beloptichene, the Upper Campanian–Maastrichtian predominantly consists of silty to fine-sandy marlstones, infrequently interbedded with sandstones and marly limestones. The sandstones are more prominently represented in the lower part of the section. These strata are overlain by a terrigenous Danian succession of sandstones, with interbeds of silty to fine-sandy marlstones, and conglomerates that vary in thickness. The present study is primarily focused on the clay-carbonate sediments in the lower half of the section.

Samples for calcareous nannofossil investigation were taken at a 0.5–1-m resolution. The recovered assemblages were abundant and taxonomically diverse. However, compared to the Kladorub section (Granchovski, 2019), the preservation is poor. The majority of specimens had been affected by secondary calcite dissolution and/or overgrowth, and a large proportion of them were difficult to identify. Fragmentation was also present. In terms of biostratigraphy, the following Upper Campanian–Lower Maastrichtian (sub)zones were identified: UC15e^{TP} (*pars*.), UC16a^{TP}, UC16b^{TP} and UC17 (*pars*.). Due to an unconformity, which was not observed in the field, UC17 (Lower Maastrichtian) was immediately overlain by NP3 (Danian), with NP3 extending into the overlying terrigenous sediments. Thus, it was concluded that, unlike in the Kladorub section (Stoykova et al., 2020), the geological record of the CMBE in the Beloptichene section is incomplete. This work was carried out through the National Science Program's 'Environmental Protection and Reduction of Risks of Adverse Events and Natural Disasters' (No. 577/17.08.2018) and supported by the MES of Bulgaria (Agreement No. D01-279/03.12.2021).

References

Granchovski, G. 2019. Calcareous nannofossils from the Upper Campanian–Maastrichtian (Upper Cretaceous) in the Kladorub Formation (Kula tectonic zone, NW Bulgaria). *Geologica Balcanica*, **48**(1): 73–101.

Stoykova, K., Granchovski, G. & Ullmann, C.V. 2020. First data on the expression of the Campanian–Maastrichtian Boundary Event in Bulgaria: Calcareous nannofossil and carbon isotope record. *Comptes rendus de l'Académie bulgare des Sciences*, **73**(12): 1711–1719.

Late Quaternary coccolith weight variations in the South China Sea and their environmental implications

Xiang Su

CAS Key Laboratory of Ocean and Marginal Sea Geology, South China Sea Institute of Oceanology, Chinese Academy of Sciences, Guangzhou 510301, China; suxiang@scsio.ac.cn

Chuanlian Liu

State Key Laboratory of Marine Geology, Tongji University, Shanghai 200092, China

Luc Beaufort

Aix Marseille University, CNRS, IRD, INRA, Coll France, CEREGE, Aix-en-Provence, France

Coccolithophores are one of the most abundant and widespread groups of calcifying plankton and have attracted extensive study in terms of their likely response to ocean acidification. Conflicting results concerning coccolithophore calcification have been reported from both experimental and field studies. Due to their minute size, it is difficult to estimate the amount of calcite in coccoliths. Here we apply the SYRACO system to analysing the weights and lengths of coccoliths produced by the dominant coccolithophore family Noëlaerhabdaceae. We obtained high-resolution coccolith weight and length records of the GEO (*Gephyrocapsa oceanica*) and SPC (*Emiliania huxleyi* and small *Gephyrocapsa* spp.) groups from sediment core MD05-2904 in the northern South China Sea (SCS) over the past 200 kyr. A calcification index (CI), based on coccolith weight and length, was applied to evaluate the changes in coccolithophore calcification. The two groups of coccolith weights/CIs showed different patterns on long-term variations and during the last two terminations. We compared the coccolith weight and CI records with the environmental variables and carbonate chemistry parameters calculated in the same core. Our data reveals that sea-surface temperature and insolation have weak correlations to coccolith weight and CI on long-term variations. The SPC weight/CI correlated with seawater pH and pCO_2 variations, while the GEO weight/CI were more related to nutrient variations. This implies a more significant role of ocean carbonate chemistry in the calcification of less-calcified coccolithophores and nutrient concentration in heavier-calcifying coccolithophores.

Influence of coccolithogenesis on coccolith size and size distribution

Baptiste Suchéras-Marx, Sophie Viseur
Aix-Marseille University, CNRS, IRD, INRAE, CEREGE, Aix-en-Provence, France; Sucheras-marx@cerege.fr
Charlotte E. Walker
Department of Biology, University of York, York YO10 5DD, UK
Ian Probert
Station Biologique de Roscoff, 29680 Roscoff, France
Clara T. Bolton, Luc Beaufort
Aix-Marseille University, CNRS, IRD, INRAE, CEREGE, Aix-en-Provence, France

Biometry is a very common tool used by the calcareous nannofossil community, helping to differentiate species, recognise stratigraphic intervals or identify palaeoceanographic events. Concerning the palaeoceanographic aspects, a reduction in coccolith size is often argued to be linked to an environmental stress. However, some species have a wide variation in coccolith size within a single coccosphere, thus the reliability of this tool is questionable. We discuss the variation in coccolith size over the life-cycle of one cell. These biological observations were used to set a numerical growth model and discuss coccolith size distributions. The results showed that: 1) a cell can produce small and large coccoliths depending on when the coccolith is produced during the life-cycle; 2) a direct correlation between coccolith size and cell size is true only at the time of coccolithogenesis; 3) a coccolith in a coccosphere could be a relic of a previous life-cycle; and 4) coccolith size may not be normally distributed. All these observations remind us that biometry is a powerful tool only if applied with a strict methodology.

Coccolithophore blooms identified in the western Pacific during the mid-Brunhes dissolution interval

Hanjie Sun
CAS Institute of Oceanology, Qingdao, Shandong 266071, China; sunhanjie@qdio.ac.cn

Baizheng An
Linyi University, Linyi City, Shandong 276005, China

Tiegang Li
First Institute of Oceanography, SOA, Qingdao, Shandong 266071, China

Rongtao Sun
Shandong University of Technology, Zibo, Shandong 255049, China

Fengming Chang
CAS Institute of Oceanology, Qingdao, Shandong 266071, China

The MD06-3050 Calypso core (15º57.0943'N, 124º46.7747'E, 2967 m water depth) and MD06-3047 Calypso Square core (17º00.44'N, 124º47.93'E, 2510 m water depth), recovered from the western Pacific, were used to construct palaeoceanographic scenarios for the mid-Brunhes in a region with an important role in global ocean–atmosphere transfer. Coccolithophore (calcareous nannofossil) and planktonic foraminiferal assemblages were collected. The record of coccolithophore assemblages showed similar trends in MD06-3047 and MD06-3050. The coccolithophore assemblages had relatively high proportions of *Florisphaera profunda* and *Gephyrocapsa* spp. in both cores. These species are abundant or present in high proportions in tropical waters. The interval from Marine Isotope Stages (MISs) 8 to 14 displayed assemblages dominated by small *Gephyrocapsa*, especially *G. caribbeanica*, the highest values being seen in the interval covering the Mid-Brunhes Event, accompanied by a clear reduction in other tropical species. Although the ecological interpretation of *G. caribbeanica* is controversial due to a clear evolutionary overprint, the high abundance of this species in the western Pacific could play an important role in deep-ocean carbonate dissolution that could be inferred from the record of the planktonic foraminifera assemblages. By analysing variations in the dominant and common species, it was found that dissolution played an important role in the preservation of the planktonic foraminifera assemblages. The relative abundances of soluble species, such as *Globigerinoides ruber* and *G. sacculifer*, showed similar trends to variations in the planktonic foraminifera fragmentation ratios over the last 1 Myr. Contrastingly, the relative abundances of dissolution-resistant species, such as *Pulleniatina obliquiloculata*, display low values during glacial intervals, but high values in interglacials. The planktonic foraminiferal assemblage in MD06-3050 was obviously influenced by dissolution during the Mid-Brunhes Dissolution Interval (MBDI) because it was characterised by a remarkable decrease in mixed-layer species, such as *G. ruber* and *G. sacculifer*. Due to long-term low values during the MBDI, the planktonic foraminifera accumulation rate for all the planktonic and some common species could be used as effective dissolution proxies in MD06-3050 at a water depth of 2967 m. However, the deep-water carbonate concentration showed high values, except for the extremely low values during MIS 11 in MD06-3047 at a water depth of 2510 m. Based on the different responses to the deep-water carbonate preservation conditions of the coccolith bloom event between these two nearby cores, we propose that the deep-sea carbonate chemistry in the western Pacific is not influenced directly by regionally enhanced surface productivity and pore-water undersaturation, but rather by the basin-wide carbonate compensation depth.

Jurassic–Cretaceous boundary interval in the Ropice section from the perspective of biostratigraphy, stable isotopes and palaeomagnetism

Andrea Svobodová
Czech Academy of Sciences, Institute of Geology, Rozvojová 269, CZ-165 00 Prague, Czech Republic
Lilian Švábenická
Czech Geological Survey, CZ-118 21 Praha, Klárov 131/3, Czech Republic; lilian.svabenicka@geology.cz
Daniela Reháková
Comenius University, Faculty of Natural Sciences, Ilkovičova 6, SK-842 15 Bratislava, Slovakia
Miroslav Bubík
Czech Geological Survey, CZ-658 69 Brno, Leitnerova 22, Czech Republic
Lucie Vaňková, Martin Košťák
Faculty of Science, Charles University, Albertov 6, CZ-128 43, Czech Republic
Petr Skupien
Technical University of Ostrava, Institute of Geological Engineering, 17 Listopadu 15, CZ-708 33 Ostrava-Poruba, Czech Republic
Tiiu Elbra, Petr Pruner
Czech Academy of Sciences, Institute of Geology, Rozvojová 269, CZ-165 00 Prague, Czech Republic

The Tithonian/Berriasian boundary in the Ropice section is situated near Český Těšín, Czech Republic. The strata belong to the Silesian Nappe Unit of the Outer Flysch Carpathians. The boundary interval comprises turbiditic limestones (grainstones, packstones and wackestones) interbedded with marlstones (mudstones). The limestones contain calpionellids, calcareous foraminifera and calcareous dinoflagellate cysts. The mudstones provide calcareous nannofossils, siliceous agglutinated foraminifera and organic-walled dinocysts. The lowermost Berriasian was determined based on the co-occurrence of *Nannoconus wintereri* and an acme of *Calpionella alpina*.

The nannofossils were mostly etched by dissolution throughout the section. There were characteristic abundances of the genera *Watznaueria* (±76%) and *Cyclagelosphaera* (±19%) forming the main components of the assemblages. Stratigraphically important nannoconids, *Polycostella beckmannii*, *Helenea chiastia* and *Cruciellipsis cuvillieri* were found rarely. The first occurrence of *N. wintereri* confirmed the NC0a subzone of Casellato and Erba (2021).

The calpionellids were relatively well preserved. A microfacies analysis revealed the presence of several index taxa for the standard calpionellid zones and subzones, including the: latest Early Tithonian Chitinoidella Zone (Boneti Subzone); Late Tithonian Crassicollaria Zone (Remanei, Intermedia and Colomi Subzones); and Early Berriasian Calpionella Zone (Alpina Subzone).

Small calcareous foraminifera (*Spirillina*, *Trocholina*, *Lenticulina*) and agglutinated foraminifera (*Pseudoreophax cisovnicensis*, *Pseudonodosinella troyeri*, *Ammogloborotalia quinqueloba*, *Caudammina silesica*) had low biostratigraphic value.

The dinoflagellate cyst association of *Mendicodinium groenlandicum*, *Systematophora areolata* and *S. orbifera* of Late Tithonian age occurred in the lower part of the section. The presence of *Amphorula delicata*, *Muderongia longicorna* and *M. tabulata* correlated well with the lowermost Berriasian Alpina Subzone.

The stable isotope record ($\delta^{18}O$, $\delta^{13}C$) showed mostly lower positive values for $\delta^{13}C$ (~0.5‰ PDB), with several negative excursions reaching ~-1.7‰ PDB, and typically negative values for $\delta^{18}O$ (~-4.2‰ PDB). The weak $\delta^{13}C$ signal was consistent with the majority of the Outer Flysch Carpathian sections in the Jurassic/Cretaceous boundary interval.

The magnetic data indicated an extensive remagnetisation, with the presence of the weathering product, goethite, along the whole section. The average magnetic susceptibility and natural remanent magnetisation showed low values of 48 × 10^{-6} SI and 0.17 mA/m, respectively. The highest susceptibility (143 × 10^{-6} SI) was found in Bed 15. Acknowledgements: This research is supported by the Czech Science Foundation (Project No. 20-10035S), and accords with Research Plan Nos. RVO67985831 and DRKVO/ČGS 2018–2022. The microfacies, calpionellid and calcareous dinocyst investigations were funded by a project of the Slovak Grant Agency (No. APVV-20-0079) and by VEGA 2/0013/20.

References

Casellato, C.E. & Erba, E. 2021. Reliability of calcareous nannofossil events in the Tithonian–Early Berriasian time interval: Implications for a revised high-resolution zonation. *Cretaceous Research*, **117**.

Primary productivity, monsoon strength and coccolith export in the north-western Bay of Bengal over the Late Pleistocene

Phyo Thant
Aix-Marseille University, CNRS, IRD, INRAE, CEREGE, Aix-en-Provence, France & University of Lille, France; phyowaithant60@gmail.com
Alexis Licht, Luc Beaufort, Yves Gally, Sandrine Conrod, Clara Bolton
Aix-Marseille University, CNRS, IRD, INRAE, CEREGE, Aix-en-Provence, France

The South Asian Monsoon is the world's largest hydrological phenomenon, and its seasonal winds and precipitation impact the livelihood of billions of people on the subcontinent. Understanding its variability in the past, and the interplay between monsoon winds and precipitation, the ocean carbon cycle, and climate forcing mechanisms, is therefore of paramount importance for the prediction of monsoons in the future.

Here, we present new high-resolution records from International Ocean Discovery Program (IODP) Site U1446 in the Mahanadi Basin, north-western Bay of Bengal, a region strongly influenced by freshwater runoff from India. This freshwater runoff, which reaches a maximum during the late summer–early autumn, following summer monsoon rains, influences the upper water-column structure and induces strong stratification, with impacts on marine primary productivity. Using new records of coccolith assemblages, masses and accumulation rates from Site U1446 sediments spanning the last ~80,000 years, we investigated the relationship between monsoon strength and runoff (based on independent proxies), coccolithophore productivity and coccolith-carbonate accumulation. We found that, during the Last Glacial Maximum, productivity and coccolith-carbonate export at Site U1446 were enhanced relative to the Holocene. We also investigated the millennial-scale variability of coccolithophore productivity in the Holocene, and its link to North Atlantic climate.

Coccolithophore responses to palaeoenvironmental variability in the Gulf of Cadiz (IODP Site U1387) through MISs 48–45

Samanta Trotta, Maria Marino
Dipartimento di Scienze della Terra e Geoambientali, Università degli Studi di Bari Aldo Moro, Bari, Italy; samanta.trotta@uniba.it

Antje Helga Luise Voelker, Teresa Rodrigues
Instituto Português do Mar e da Atmosfera, Divisão de Geologia e Georecursos Marinhos, Alges, Portugal & Centro de Ciências do Mar (CCMAR), Universidade do Algarve, Portugal

José-Abel Flores
Department of Geology, University of Salamanca, Salamanca, Spain

Patrizia Maiorano, Angela Girone, Marina Addante
Dipartimento di Scienze della Terra e Geoambientali, Università degli Studi di Bari Aldo Moro, Bari, Italy

Barbara Balestra
Environmental Science Department, American University, Washington, DC 20016, USA & Paleobiology Department, National Museum of Natural History, Smithsonian, Washington, DC 20560, USA

High temporal resolution analyses (300 years) of coccolithophore assemblages through MISs 48–45 were carried out to improve the dataset on climate variability during the '41-kyr world', prior to the Mid-Pleistocene Transition. Sediment samples were recovered from IODP Site 339-U1387, from a water depth of 558 m on the middle slope of the Faro Drift in the Gulf of Cadiz (36º48.321"N, 7º43.1321"W).

Thirty-three taxa were identified to the genus, species and subspecies level. Gephyrocapsids were the dominant group, contributing more than 85%. Reworked coccoliths and lithic or mineral elements (>10 μm) were counted separately to monitor variability in the terrigenous supply. Principal component analysis showed that temperature and productivity were the first and second factors, respectively, controlling coccolithophore assemblage composition.

The abundance fluctuations of key taxa, such as *Gephyrocapsa caribbeanica* and *Coccolithus pelagicus* ssp. *pelagicus*, warm-water taxa, and large *Gephyrocapsa* (>5.5 μm), as well as of the reworked and lithic elements, allowed the recognition of glacial (MISs 48–46) and interglacial (MISs 47–45) phases, in agreement with the *Globigerina bulloides* $\delta^{18}O$ record at the study site, reflecting the southward/northward migration of the Portugal/Iberian Poleward Currents, respectively. Short-term increases in *C. pelagicus pelagicus* abundances during the glacial phases pointed to the presence of polar meltwater, also evidencing a millennial-scale climatic variability during the Early Pleistocene.

The increases in coccolithophore productivity (CP) during short intervals in the glacial phases (MIS 48 and MIS 46) have been related to enhanced northerly wind intensity, as a consequence of the expansion of the Northern Hemisphere continental ice-sheets, leading to surface-water mixing and increased nutrient availability. Brief CP increases during the interglacial phases (MIS 47 and MIS 45) occurred during insolation maxima/precession minima that promoted an increase in rainfall and river runoff, favouring enhanced riverine nutrient supply. The co-occurrence of sapropels in the eastern Mediterranean Sea during the interglacial CP increases at the studied site supports the orbitally controlled high-precipitation-condition hypothesis, and highlights a correspondence between similar climatic conditions west and east of the Gibraltar Strait during the Early Pleistocene, as observed in Middle Pleistocene intervals (Voelker et al., 2015).

References

Voelker, A.H.L., Salguiero, E., Rodrigues, T., Jiminez-Espejo, F.J., Bahr, A., Alberto, A., Loureiro, I., Padilha, M., Rebotim, A. & Röhl, U. 2015. Mediterranean outflow and surface-water variability off southern Portugal during the Mid-Pleistocene Transition—A snapshot of Marine Isotope Stages 29 to 34 (1010–1135 ka). *Global and Planetary Change*, **133**: 223–237.

Morphological and crystallographic variation of coccoliths in the *Umbilicosphaera* (Calcidiscaceae) lineage

Masayuki Utsunomiya
Geological Survey of Japan, AIST, 1-1-1, Higashi, Tsukuba 305-8567, Japan; m.utsunomiya@aist.go.jp
Toshihiro Kogure
Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan

The morphology of placolith-type coccoliths is unique to the given species, characterised by the size of the distal and proximal shields, diameter of the central opening and shape of the suture lines, etc. These characters are basically determined by the shapes of the organic base-plate and coccolith vesicle enfolding the plate, and the crystal orientation of the initially precipitated calcite around the rim of the plate. Analysis using high-resolution scanning electron microscopy (SEM) and electron back-scattered diffraction (EBSD) can provide an understanding of the relationship between the crystallographic orientations of the shield elements and the morphologies of the coccoliths (e.g. Saruwatari et al., 2006). Such analysis allows us to understand what controls the species-specific morphology and what has changed in the evolutionary lineage of the coccolithophore. For this purpose, SEM–EBSD analyses of several taxa with direct ancestor–descendant relationships might be expected, but there are no examples of such studies, to our knowledge. The genus *Umbilicosphaera*, which is the subject of the present study, has a fossil record that runs from the Late Paleocene. *Umbilicosphaera patera* (newly described by Utsunomiya et al., 2021) is considered to be the most recent common ancestor of the extant species *U. sibogae*. The diversification of *U. sibogae* from *U. patera* occurred during the Pliocene. We obtained morphometric data and measured the *c*- and a_i-axis orientations of the distal shield elements around the central opening of these two species using SEM–EBSD. The *c*-axis of the distal shield elements of *U. patera* inclined upwards at ~55° from the coccolith plane, and one of the a_i-axes was roughly parallel to the coccolith plane. On the other hand, the *c*-axis of the distal shield element of *U. sibogae* inclined upwards at ~65° from the coccolith plane. This difference in the crystal orientation explains the nearly flat distal shield and steep inner slope around the central opening in the morphology of *U. patera* compared to those of *U. sibogae*, assuming that the facets of the distal shield elements consist of {104} planes of calcite.

References

Saruwatari, K., Ozaki, N., Nagasawa, H. & Kogure, T. 2006. Crystallographic alignments in a coccolith (*Pleurochrysis carterae*) revealed by electron back-scattered diffraction (EBSD). *American Mineralogist*, **91**: 1937–1940.

Utsunomiya, M., Hagino, K. & Tanaka, Y. 2021. Speciation of extant *Umbilicosphaera* (Prymnesiophyceae) during the Pliocene. *Marine Micropaleontology*, **169**: 102037.

The Neogene Central American Seaway

Felipe Vallejo, Andrés Pardo-Trujillo, Ángel Barbosa-Espitia, Daniela Aguirre, Sergio A. Celis, Carlos A. Giraldo-Villegas, Ángelo Plata, Raúl Trejos-Tamayo, Andrés Salazar-Ríos, Alejandro Arenas
Instituto de Investigaciones en Estratigrafía, Universidad de Caldas, Manizales, Colombia; diego.vallejo@ucaldas.edu.co

José-Abel Flores
Departamento de Geología, Universidad de Salamanca, Spain

Marie-Pierre Aubry
Department of Earth and Planetary Sciences, Rutgers University, USA

Fabián Gallego, Eduardo Delgadillo
Instituto de Investigaciones en Estratigrafía, Universidad de Caldas, Manizales, Colombia

David Foster
Department of Geologic Sciences, University of Florida, USA

Two of the world's largest oceans—the Pacific and Atlantic—have been connected through a sea passage called the Central American Seaway (CAS). The closure of this passage and separation of the two oceans have been impacted by the ongoing interaction of the Caribbean and South American Plates, readjusting oceanic currents and creating the only land bridge between South and North America. The modalities and timing of the closure during the Neogene have been the objectives of many studies, resulting in two main proposals, one for the late closure of the shallow seaway and the other for the early closure of the deep-sea connection. A Late Pliocene cessation of the flow of shallow oceanic waters between the Atlantic and Pacific Oceans has been the classic interpretation. A Middle Miocene closure of the deep-oceanic seaway along the tectonic boundary between the Panamá Arc and the oceanic rocks of the Western Cordillera of Colombia is a more recent and controversial interpretation. However, until now there has not been any direct geological evidence from the tectonic boundary to support either interpretation. This new study, which involved fieldwork along the Panamá Arc and western South American tectonic boundary, has revealed a stratigraphic record of Miocene marine sediments that were deposited in the Central American Seaway along the suture zone (CASsz). Although highly deformed and fractured, these sediments constitute the only known direct evidence of the geological history along the CASsz. Micropalaeontological, including calcareous nannofossils, U–Pb detrital geochronological and ichnological data from these deposits attest to a progressive shallowing during the latest Early to earliest Middle Miocene (16.4–15.1 Ma). Our data indicate that marine conditions were already shoaled (<120 m depth) in some sectors of the CASsz, possibly implying that water depth exchanges between the Atlantic and Pacific oceans were already affected by closure during the Early to Middle Miocene. When we combine our results with previous studies from Central America and western Colombia, our research supports several parts of the Panamá Arc having shoaled to neritic palaeodepths by the Middle Miocene, resulting in a perturbed flow of deep water across the arc and implying that the CAS should not be restricted to the suture zone (CASsz). Our findings agree with the view that the onset of the Atlantic overturning circulation preceded the Pliocene intensified cooling (2.5 Ma) of the western Northern Hemisphere by several million years (~13 Myr). The CAS was represented by different straits that closes at different times, probably vanishing in the suture zone (CASsz) by the Middle Miocene (between 15 and 12 Ma), as previously proposed. Nevertheless, well-calibrated stratigraphic sections older than the Late Miocene from Central America and western Colombia are still needed in order to better understand the geological evolution of the CAS prior to the well-known shallow oceanic disruption of the Pliocene.

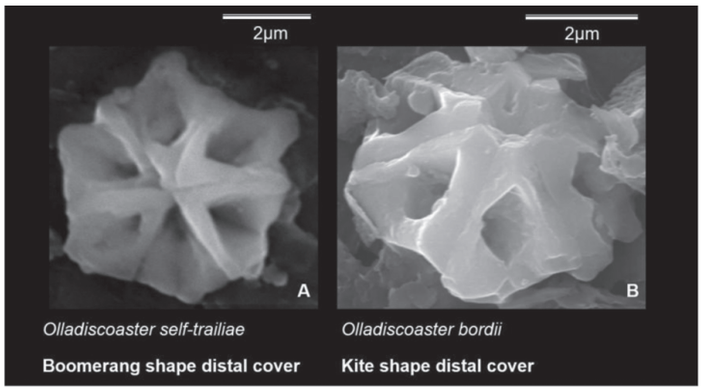
New Middle Miocene genus *Olladiscoaster*

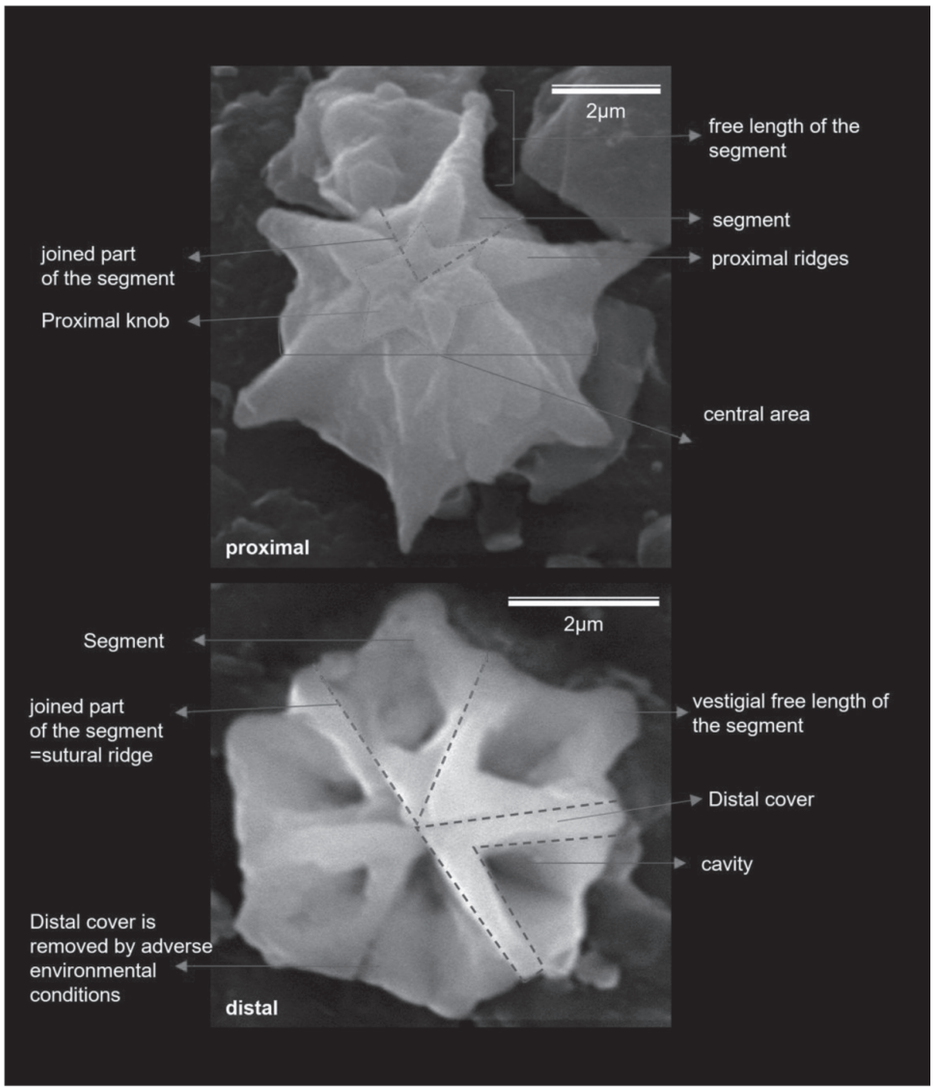
Osman Varol
Rhos-on-Sea, North Wales, UK; osman@varol.com
Andrew R. Bowman
Missouri City, TX, USA

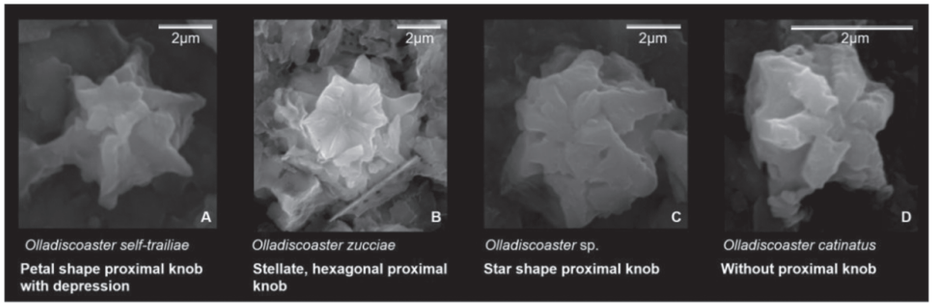
Olladiscoaster is jar-shaped and characterised by having a kite- or boomerang-shaped distal cover—the primary criterion for distinguishing it from *Discoaster*. The species' outline or central-area can be circular, hexagonal or stellate. The bulging proximal side possesses ridges and is often decorated with a stellate, hexagonal or star-shaped proximal knob, although the knob may be absent in rare cases. The sutural ridges formed by deep cavities rise towards the centre and are coated with a boomerang- or kite-shaped distal cover. *Olladiscoaster* has segments that often display vestigial free length or lack free length entirely. Species randomly settle in the plan or distal view because they possess a similar height:width ratio. Olladiscoasters are extinct in plan view (the *c*-axis is aligned with the microscope axis), but birefringent in side view, displaying strong interference colours. The samples derived from various commercial oil wells in the Gulf of Mexico, IODP Leg 354, Site U1451B, DSDP Leg 154, Site 926A and the USGS–NASA Langley core from Hampton, VA, USA. They were studied using a light-microscope (LM) and the mobile-mount technique, and with a scanning electron microscope (SEM). The different profiles for most of the species were mapped.

Olladiscoaster ranges from 14.75 to 11.90 Ma in the Middle Miocene (Zones NN5–NN7). Diverse and high abundances of *Olladiscoaster* were noted at 13.50 and 13.21 Ma (in NN6). Three groups of *Olladiscoaster* were recorded, primarily based on the characteristics of the segments. Other criteria used include the presence or absence of a proximal knob and the morphology of the knob when present. The *O. virginianus* group is characterised by having segments with free length and a hexagonal central-area with a boomerang-shaped distal cover. This group is related to the *Discoaster musicus* group and possibly evolved from them. The *O. molae* group has segments with vestigial free length and a stellate outline (except for *O. vestiguum*, which is hexagonal) and a proximal knob. The *O. bordii* group has segments with no free length and circular outlines (except for *O. perplexus*, which is hexagonal).

Ten new species—*O. artatus*, *O. bordii*, *O. cruzii*, *O. lepidus*, *O. molae*, *O. perplexus*, *O. self-trailiae*, *O. superbus*, *O. vestiguum* and *O. zucciae* have been described. Three new combinations—*O. catinatus*, *O. tokerae* and *O. virginianus*—have been introduced.


2µm
2µm
A
B
Olladiscoaster self-trailiae
Boomerang shape distal cover
Olladiscoaster bordii
Kite shape distal cover


2µm
free length of the segment
segment
proximal ridges
joined part of the segment
Proximal knob
central area
proximal
2µm
Segment
joined part of the segment =sutural ridge
vestigial free length of the segment
Distal cover
cavity
Distal cover is removed by adverse environmental conditions
distal


2µm
2µm
2µm
2µm
A
B
C
D
Olladiscoaster self-trailiae
Petal shape proximal knob with depression
Olladiscoaster zucciae
Stellate, hexagonal proximal knob
Olladiscoaster sp.
Star shape proximal knob
Olladiscoaster catinatus
Without proximal knob

Surface-sediment coccolith assemblages and *Emiliania huxleyi* morphotype calcification across the Drake Passage, Southern Ocean

Nele Manon Vollmar
Previously University of Bremen, Department of Geosciences, Klagenfurter Strasse 2-4, 28359 Bremen, Germany & now NORCE Norwegian Research Centre, Climate & Environment, Bergen, Norway; nevo@norceresearch.no

Karl-Heinz Baumann
University of Bremen, Department of Geosciences, Klagenfurter Strasse 2-4, 28359 Bremen, Germany; baumann@uni-bremen.de

Mariem Saavedra-Pellitero
School of Geography, Earth and Environmental Sciences, University of Birmingham, Birmingham B15 2TT, UK

Iván Hernández-Almeida
Department of Earth Science, ETH Zurich, Sonneggstrasse 5, 8092 Zurich, Switzerland

The physical and biogeochemical properties of the Southern Ocean (SO) are experiencing rapid and profound changes that may influence the distribution and composition of pelagic plankton communities. The most prolific carbonate-producing phytoplankton group—the coccolithophores—play an important role in SO biogeochemical cycles. Although records of (sub-)fossil coccolith assemblages constitute invaluable indicators for palaeoenvironmental reconstructions, knowledge on the SO is scarce.

This study investigated the coccolith assemblages preserved in surface sediments across the Drake Passage, retrieved during the R/V *Polarstern* Expedition PS97. We focused on the coccolith response to steep environmental gradients across the frontal system of the Antarctic Circumpolar Current. We also examined the morphological diversity of *Emiliania huxleyi*, emphasising biogeographical variability, coccolith size and calcite carbonate-mass estimations.

North of the Polar Front, the surface sediments provide suitable material for reconstructing the overlying surface-ocean conditions. Comparatively high coccolith abundances and species diversity occurred especially south of the Polar Front. Here, further factors, such as temporarily thriving coccolithophore communities in the surface waters or the transport of settling coccoliths via surface and bottom currents and eddies, have influenced the (sub-)fossil coccolith assemblages. Additionally, deeper samples in the southern part of the study area were particularly affected by selective carbonate dissolution.

We identified five *E. huxleyi* morphotypes (A, A overcalcified, R, B/C and O). The *E. huxleyi* morphologies reflect diverging biogeographical distributions, trending towards smaller and lighter coccoliths to the south, and emphasising the importance of documenting those morphologies in relation to changing environmental conditions in order to assess their response to projected environmental change in the SO.

Interregional correlations and sea-level changes in Middle Paleocene–Early Eocene of the eastern Tethys Sea (Central Asia): Calcareous nannofossil evidence from the western Tarim Basin, north-western China

Xuejiao Wang
State Key Laboratory of Biogeology and Environmental Geology, China University of Geosciences, Xueyuan Road 29, Haidian District, Beijing 100083, China & Université Lyon, UCBL, ENSL, UJM, CNRS, UMR 5276 LGL-TPE, F-69622 Villeurbanne, France & Institut Universitaire de France, Paris, France; xuejiaowang410@hotmail.com

Emanuela Mattioli
Laboratoire de Géologie de Lyon: Terre, Planètes, Environnement (UMR 5276, CNRS) Université Lyon 1, Ecole Normale Supérieure Lyon, Campus scientifique de la Doua, 69622 Villeurbanne, France

Dangpeng Xi
State Key Laboratory of Biogeology and Environmental Geology, China University of Geosciences, Xueyuan Road 29, Haidian District, Beijing 100083, China

Calcareous nannofossil assemblages from the interval covering the Middle Paleocene to Early Eocene (P/E), studied in sediments from two sections in the western Tarim Basin (Bashibulake and Kuzigongsu), indicate a record of the Paleocene–Eocene Thermal Maximum (PETM) inscribed in a transgression–regression cycle. The transgression was interpreted on the basis of species richness and abundance increasing gradually from the base of the Qimugen Formation (dated as NP7–NP9a, Thanetian), in which the first occurrences of *Heliolithus riedelii* and *Discoaster multiradiatus* have been recorded. The turnover of the sea-level cycle coincided with increasing *Discoaster* spp. amounts near the P/E boundary (NP9b–NP10), which was dated by the occurrence of assemblages containing *Rhomboaster* spp. and the *D. araneus* group. Evidence of regression, indicated by low nannofossil abundances and diversity, was observed at the top of the Qimugen Formation (NP10), coinciding with assemblages characterised by rapidly increasing *Micrantholithus* spp. and constantly low abundances and diversity of nannofossils. The sea-level change in the Bashibulake section occurred close to the boundary of NP9a/NP9b, and was recorded earlier than in the Kuzigongsu section, where an abrupt decrease in abundance of *Discoaster* spp. was observed below the dissolution zone, while an increase in *M. astrum* was noted in the aftermath of the event. Interregional correlations, established thanks to the variations in calcareous nannofossil assemblages in the two sections, suggest that sea-level changes in the southern part of the Tarim Basin occurred earlier than to the west.

Regression of the Tethys Sea from Central Asia during the Middle to Late Eocene: Evidence from calcareous nannofossils of the western Tarim Basin, north-western China

Xuejiao Wang
State Key Laboratory of Biogeology and Environmental Geology, China University of Geosciences, Xueyuan Road 29, Haidian District, Beijing 100083, China & Université Lyon, UCBL, ENSL, UJM, CNRS, UMR 5276 LGL-TPE, F-69622 Villeurbanne, France & Institut Universitaire de France, Paris, France; xuejiaowang410@hotmail.com

Dangpeng Xi
State Key Laboratory of Biogeology and Environmental Geology, China University of Geosciences, Xueyuan Road 29, Haidian District, Beijing 100083, China

David K. Watkins
Department of Earth and Atmospheric Sciences, University of Nebraska, Lincoln, NE 68588-0340, USA

Jean M. Self-Trail
Florence Bascom Geoscience Center, US Geological Survey, 926a National Center, Reston, VA 20192, USA

Calcareous nannofossil assemblages from Middle to Upper Eocene sediments of the western Tarim Basin indicate two important episodes of marine incursion into the basin. The first episode represents a period of shallowing upwards in the Wulagen Formation, and is dated as Zone CNE13 (Lutetian) by the co-occurrence of *Discoaster bifax*, *Chiasmolithus solitus* and common *Reticulofenestra umbilicus*. The presence of a diverse assemblage of discoasters in the basal Wulagen Formation suggests deposition occurred in oligotrophic, warm waters with a connection to the open ocean. Progressive shallowing over time led to the formation of a restricted basin in which only *Coccolithus pelagicus* could survive. The second major episode of marine incursion is preserved in the middle part of the Bashibulake Formation, which is dated as Zone CNE17 (Bartonian/Priabonian) based on the presence of common *Cribrocentrum erbae*. The interval between the two marine incursions was dominated by subaerial exposure and evaporation, resulting in the deposition of gypsum at the top of the Wulagen Formation. Although maximum regression at the end of the Lutetian was followed by sea-level rise at the beginning of the Bartonian, globally, it is clear that local tectonics played a crucial role in regional marine incursions into the Tarim Basin during deposition of the Wulagen Formation.

Evolution of Miocene calcareous nannofossil assemblages as a response to palaeoceanographic changes in the northern South China Sea

Yasu Wang
College of Oceanography, Hohai University, Nanjing 245700, China; wys199187@163.com

Hoshina Kazuki
Department of Earth and Environmental Sciences, Yamagata University, Yamagata 990-8560, Japan

Hong Su
College of Life Science and Technology, Jinan University, Guangzhou 510632, China

Richard W. Jordan
Department of Earth and Environmental Sciences, Yamagata University, Yamagata 990-8560, Japan

Shijun Jiang
College of Oceanography, Hohai University, Nanjing 245700, China

The South China Sea (SCS) is the largest marginal sea in the western Pacific, and is located in the west Pacific warm pool (WPWP) and in a key region of global thermohaline circulation. The thick sedimentary sequence in the SCS represents a complete and continuous record of tectonic, palaeoclimatic and palaeoceanographic changes, therefore making the SCS an important area for studying Cenozoic palaeoenvironments. Here, we selected the continuous sediment archives obtained from International Ocean Discovery Program (IODP) Site U1501 on the northern margin of the SCS for biostratigraphic and palaeoceanographic study. A quantitative analysis of the calcareous nannofossil assemblages was performed, in combination with $CaCO_3$ (wt%) measurements, to investigate the palaeoceanographic changes in the SCS between 15 and 5 Ma.

Totals of 117 calcareous nannofossil species in 32 genera were identified in the 217 samples from IODP Site U1501. The common taxa included *Reticulofenestra* (*R. minuta*, *R. minutula*, *R. haqii*, *R. pseudoumbilicus*), *Florisphaera profunda*, *Cyclicargolithus floridanus*, *Discoaster* (*D. berggrenii*, *D. brouweri*, *D. pentaradiatus*, *D. quinqueramus*, *D. variabilis*), *Helicosphaera carteri*, *Calcidiscus leptoporus*, *Coccolithus pelagicus*, *Sphenolithus* (*S. abies*, *S. moriformis*, *S. heteromorphus*) and *Umbilicosphaera* (*U. jafari*, *U. rotula*). Small *Reticulofenestra* spp. were predominant throughout the Middle Miocene, indicating high marine productivity. The *Umbilicosphaera*, *Discoaster* and large *Reticulofenestra* spp. (*R. pseudoumbilicus*, *R. perplexa*) abundances showed rapidly increasing trends from the Middle to Late Miocene, their high abundances possibly indicating low-fertility conditions. The $CaCO_3$ (wt%) and total shield index decreased in this interval, reflecting the decrease in marine productivity and enhancement of carbonate dissolution, which coincided with the carbonate crash. Then, the abundance of small *Reticulofenestra* spp. and $CaCO_3$ (wt%) gradually increased synchronously, indicating that marine productivity gradually recovered and carbonate preservation improved.

The evolution of the calcareous nannofossil assemblages mentioned above reflects the palaeoceanographic changes that occurred from the Middle Miocene to Early Pliocene in the SCS. During the Middle Miocene, the Indonesia Seaway was not completely closed, and therefore the thermocline was shallow and surface mixing was strong, which may have provided sufficient nutrients to maintain high marine productivity. Then, at the Middle/Late Miocene boundary, the proto-WPWP was formed due to the constriction of the Indonesian Seaway, which deepened the thermocline, weakened the surface mixing and reduced the nutrient supply from the deep sea, thereby reducing productivity and biogenic carbonate production, leading to the carbonate crash event. Subsequently, enhanced monsoon circulation and continental weathering led to an increase in the nutrient supply, which increased marine productivity from the Late Miocene to the Pliocene, leading to the biogenic bloom event in the SCS. Acknowledgements: This work was jointly funded by the National Natural Science Foundation of China (Nos. 41976045, 41888101) and the Southern Ocean Science and Engineering Guangdong Laboratory (Zhuhai) Innovation Team Construction Project (No. 311021002).

A high-resolution depth profile of coccolithophores in oligotrophic waters of the North Atlantic gyre

Amos Winter
Earth and Environmental Systems, Indiana State University, Terre Haute, IN 47809, USA; amos.winter@indstate.edu

Hartmut Schulz
Faculty of Sciences and Mathematics, Tübingen University, Germany

Jeremy R. Young
Earth Sciences, University College London, Gower Street, London, UK

Richard Lotspeich
Department of Economics, Indiana State University, Terre Haute, IN 47809, USA

Liam Hood, Josue J. Millan, Christian Sizemore
Earth and Environmental Systems, Indiana State University, Terre Haute, IN 47809, USA

We report abundances and vertical distributions of coccolithophore species from water samples retrieved on 28 January, 2015 by the R/V *Meteor* during the M113/2 cruise, at Station #39, located at ~31.46ºN, 44.44ºW in the North Atlantic Gyre. Whenever possible, at least 300 specimens from 24 depths, from the surface to 400 m, were evaluated by scanning electron microscope to determine the community composition. This location is representative of oligotrophic regions of oceans with a deep Chl-a maximum at 120 m, where we observed abundant coccolithophores. Oligotrophic regions account for 70% of the photosynthetic volume of the oceans. We are seeking to understand the contribution of the coccolithophores in this region to the biogeochemical cycling of carbon.

The V/R model of heterococcolith biomineralisation 30 years on: Unanswered questions and continuing relevance

Jeremy R. Young, Paul R. Bown
Earth Sciences, University College London, London WC1E 6BT, UK; jeremy.young@ucl.ac.uk

The V/R model of coccolith biomineralisation was first published by Young et al. (1992)—so, 30 years ago. Broadly, this consisted of: 1) the observation that the biomineralisation of heterococcolith rims commonly commenced with the nucleation of calcite microcrystals with alternately sub-vertical (V) and sub-radial (R) crystallographic *c*-axis orientations; 2) the observation that this pattern was conserved through the 230-Myr evolutionary history of heterococcoliths and so likely provided a key to studying the homology between taxa; 3) a hypothesis that the nucleation might be controlled by a plicated macromolecular template located around the rim of the cellulosic baseplate.

The model has generally held up well, with support both from its application across the biodiversity of extant and fossil heterococcoliths, and from detailed studies of biomineralisation in particular species. Nonetheless, numerous questions posed by the model remain unanswered and, perhaps more surprisingly, many taxonomists largely ignore it. This talk will discuss some of the unanswered questions related to the V/R model and why it continues to be a key tool in understanding coccolith evolution and taxonomy. Unanswered questions include: Is there a precursor template for the nucleation template, and, if not, how does the biological system precisely control the orientation and spacing of the nuclei? Are the V/R orientations precisely 90º apart or does this vary? Nucleation spacing varies around the rim of coccoliths, is this geometrically determined or altered by design? Is the variation in nucleation spacing and chirality phylogenetically significant? Nucleation in holococcoliths, in many heterococcolith central-areas and in many nannoliths does not show the V/R pattern—are these radically different biomineralisation modes or are they modifications of the typical V/R mode? Do the Syracosphaeraceae really show a V/R/T pattern of nucleation?

The relevance of the V/R model to practical taxonomy will be discussed with reference to Palaeogene placoliths, such as *Aliculosphaera*, *Centumgemina*, *Ericsonia*, *Hornibrookina* and *Toweius*. More generally, it will be argued that nannofossil taxonomy requires: 1) tracing of the interconnections of elements to form crystal units; 2) determination of the *c*-axis orientation of crystal units; and so 3) integrated use of electron microscopy and light microscopy (including the use of accessory plates and phase-contrast).

Nannotax: Bibliography project and other updates

Jeremy R. Young
Earth Sciences, University College London, London WC1E 6BT, UK; jeremy.young@ucl.ac.uk

Ines Galović
Croatian Geological Survey, Sachsova 2, 10000 Zagreb, Croatia

Richard W. Howe
Ellington Geological Services, 1414 Lumpkin Rd, Houston, TX 77043, USA

Shijun Jiang
College of Oceanography, Hohai University, Nanjing, China

Baptiste Suchéras-Marx
Aix Marseille University, CNRS, IRD, INRAE, CEREGE, Aix-en-Provence, France

The *Nannotax* website was officially launched in something close to its current form at the INA13 conference in Washington in 2013. Since then, it has both become the prime online resource for the taxonomy of living and fossil coccolithophores and has also been continuously developed, expanded and updated. This was a lockdown-compatible activity and so has continued through the last few years. General updates since the last INA conference in 2019 have included adding around 5000 more images, from about 150 publications, 200 new taxon descriptions in the Farinacci & Howe catalogue and many edits to the main database, but with more still to do. Three significant changes to the data structure and capability have also been made, and these will be outlined in this talk.

1. *Image sorting and searching*. The images are now classified by image type, such as SEM–distal, SEM–coccosphere, LM–coccosphere, etc. This is used to sort images on the pages. In parallel, new image search tools have been developed. Together, these allow the increasingly large collections of images for single taxa to be used for research.

2. *Advanced search*. The original advanced-search system introduced in 2017 was based on a very large vocabulary of descriptive terms and did not prove very useful or popular. This has now been replaced by a simpler set of terms with a graphic interface, which is, hopefully, quicker and easier to use, while still allowing rapid narrowing of the field of possible identifications.

3. *Expanded bibliography and PDF collection*. This has been a major project, carried out with Baptiste Suchéras-Marx, Shijun Jiang and Ines Galović. The objective was to develop a rather comprehensive bibliography of the literature on nannofossils and nannoplankton and a linked PDF collection. This required improved databasing of the bibliography, databasing of the copyright/open access status of journals, and developing new scripts to link PDFs to references. In parallel, bibliographies and PDF collections from multiple sources have been merged and cleansed. As a result, the *Nannotax* bibliography now contains 4630 references (vs 1900 in 2019), with PDF copies available for 3400 of these.

Evolution of upper seawater stratification in the South China Sea central basin during the Late Miocene

Xinquan Zhou, Chuanlian Liu
Tongji University, State Key Laboratory of Marine Geology, 1239 Siping Road, Shanghai 200092, China; xinquan_zhou@tongji.edu.cn

The South China Sea (SCS)—the largest semi-enclosed marginal sea in the western Pacific Ocean—is an excellent site for exploring tropical seawater evolution in response to tectonic activity in geological time. Most of the previous studies on long time-scales have relied on sediment cores obtained from its continental margins. Here, we provide a Late Miocene record of upper seawater stratification reconstructed using variations in calcareous nannofossil assemblages from the SCS central basin, which has an average water depth of 4700 m. The Upper Miocene unit of IODP Site U1433 (studied here) consists of alternate carbonate and clay layers. The genesis of these carbonate layers by turbidity currents was supported by both the sedimentology and the presence of reworked coccoliths. The clay layers can be viewed as pelagic deposits, and thus can be used for palaeoenvironmental reconstruction. A calcareous nannofossil biostratigraphy of the Late Miocene (~10 to 5 Ma) is provided, based on the studied clay samples.

Calcareous nannofossil abundances and assemblages were used to reconstruct the evolution of the upper seawater structure. The absolute abundance of total calcareous nannofossils showed a significant increase at ~8 Ma associated with changes in the relative contributions of small reticulofenestrids and oligotrophic species. Our results indicate that the upper seawater shifted from strongly stratified to well-mixed accompanied by an increase in pelagic productivity at ~8 Ma. This shift was due to the closure of the Indonesian Seaway, an enhanced summer monsoon over the SCS, and higher Mekong river input driven by the uplift of the Vietnam Central Highland.

Mid-Eocene thermals record in the Istrian Paleogene Basin (Outer Dinarides, Croatia), Neotethys

Renata Lukić

Department of Geology, Faculty of Science, University of Zagreb, Horvatovac 102b, 10000 Zagreb, Croatia

Stjepan Ćorić

Geological Survey of Austria, Neulinggasse 38, 1030 Vienna, Austria

Ines Galović*, Marija Horvat

Croatian Geological Survey, Sachsova 2, 10000 Zagreb, Croatia; ingalovic@hgi-cgs.hr

Katja Mužek, Đurđica Pezel, Vlasta Ćosović

Department of Geology, Faculty of Science, University of Zagreb, Horvatovac 102b, 10000 Zagreb, Croatia

Several short sections from Istria, northern Adriatic (Racani—Rac, <5 m; Jakomići—J, ~6 m and Jak, ~2 m), were studied micropalaeontologically and geochemically. The top *Nannotetrina* spp. (*N. cristata*) (42.97 Ma) and base common *Reticulofenestra umbilicus* (42.3 Ma) point to Zone NP16 (Martini, 1971) and the Lutetian MNP16A (Fornaciari et al., 2010; Agnini et al., 2014), which agree with the foraminiferal E10/E11 zonal boundary in the Racani section (Berggren & Pearson, 2005). This interval is known as the Late Lutetian Thermal Maximum (Westerhold et al., 2020). The interpreted peak climatic condition is reflected in the relatively high species richness (73) and the rapid deposition of two organic-rich intervals (7.25% TOC), which may be associated with the increase in the concentration of sulphur (0.29% TOC/S) and low concentration of Mn (0.09%), implying low-oxygen, possibly dysoxic, bottom-water conditions (Spofforth et al., 2010 and references therein). The warm-water species *Cyclicargolithus floridanus* dominated (up to 52%) the assemblages, indicating meso-oligotrophic conditions (Toffanin et al., 2011).

In the Mediterranean, the base *Furcatolithus obtusus* (39.63 Ma) coincides with the top *Sphenolithus spiniger* (39.63 Ma), which was recorded at the top of Section J, indicating Bartonian Subzone MNP16Bc (= NP17), which indicates Chron C18n2n (Fornaciari et al., 2010). The domination of the warm-water *Reticulofenestra bisecta* (21%) points to the enhanced eutrophic conditions that characterised the carbon isotope excursion phase of the Middle Eocene Climatic Optimum (MECO) (D'Onofrio et al., 2021 and reference therein), with continued high (71) species richness.

The base *Furcatolithus obtusus* at the base (in the first metre) of the Jak section defines the base of Subzone MNP17A, which agrees with the top *S. spiniger* (which occurred in the second metre of the section). The warm-water *Reticulofenestra producta* increased (by up to 25%), suggesting more shallow and mesotrophic conditions (Wade & Bown, 2006), with the decreased species richness (65) characteristic of the post-MECO phase (D'Onofrio et al., 2021).

The composition of the planktonic foraminiferal assemblages (predominantly thermocline-dwelling *Subbotina* and common subsurface-dwelling *Turborotalia*) and the low proportion of smaller benthic foraminifera (15% in J, 3.8–5.4% in Jak and 20% in Rac) indicate eutrophic to mesotrophic conditions in the lower bathyal (Murray, 1991), stratified water column (Pearson et al., 2001). This study was undertaken within the framework of the Croatian Science Foundation Project IP-2019-04-5775 BREEMECO.

References

Agnini, C., Fornaciari, E., Raffi, I., Catanzariti, R., Pälike, H., Backman, J. & Rio, D. 2014. Biozonation and biochronology of calcareous nannofossils from low and middle latitudes. *Newsletters on Stratigraphy*, **47**: 131–181.

Berggren, W.A. & Pearson, P. 2005. A revised tropical to subtropical Paleogene planktonic foraminiferal zonation. *Journal of Foraminiferal Research*, **35**: 279–298.

D'Onofrio, R., Zaky, A., Frontalini, F., Luciani, V., Catanzariti, R., Francescangeli, F., Giorgioni, M., Coccioni, M., Ozcan, E. & Jovane, L. 2021. Impact of the Middle Eocene Climatic Optimum (MECO) on foraminiferal and calcareous nannofossil assemblages in the neo-Tethyan Baskil section (eastern Turkey). Paleoenvironmental and paleoclimatic reconstructions. *Applied Sciences*, **11**.

Fornaciari, E., Agnini, C., Catanzariti, R., Rio, D., Bolla, E.M. & Valvasoni, E. 2010. Mid-latitude calcareous nannofossil biostratigraphy, biochronology and evolution across the Middle to Late Eocene transition. *Stratigraphy*, **7**: 229–264.

Martini, E. 1971. Standard Tertiary and Quaternary calcareous nannoplankton zonation. *In*: A. Farinacci (Ed.). *Proceedings II Planktonic Conference, Rome, 1970. Tecnoscienza*, **1**: 738–785.

Murray, J.W. 1991. Ecology and paleoecology of benthic foraminifera. John Wiley and Sons, New York: 1–397.

Pearson, P.N., Ditchfield, P.W., Singano, J., Harcourt-Brown, K.G., Nicholas, C.J., Olsson, R., Shackleton, N.J. & Hall, M.A. 2001. Warm tropical sea surface temperatures in the Late Cretaceous and Eocene epochs. *Nature*, **413**: 481–487.

Spofforth, D.J.A., Agnini, C., Pälike, H., Rio, D., Fornaciari, E., Giusberti, L., Luciani, V., Lanci, L. & Muttoni, G. 2010. Organic carbon burial following the Middle Eocene climatic optimum in the central western Tethys. *Paleoceanography*, **25**.

Toffanin, F., Agnini, C., Fornaciari, E., Rio, D., Giusberti, L., Luciani, V., Spofforth, D.J.A. & Pälike, H. 2011. Changes in calcareous nannofossil assemblages during the Middle Eocene Climatic Optimum: Clues from the central western Tethys (Alano section, NE Italy). *Marine Micropaleontology*, **81**: 22–31.

Westerhold, T., Marwan, N., Drury, A.J., Liebrand, D., Agnini, C., Anagnostou, E., Barnet, J.S., Bohaty, S.M., De Vleeschouwer, D., Florindo, F. & Frederichs, T. 2020. An astronomically dated record of Earth's climate and its predictability over the last 66 million years. *Science*, **369**: 1383–1387.

We hope you enjoyed INA18 in Avignon...

See you in 2024 in another nanno-tastic location!